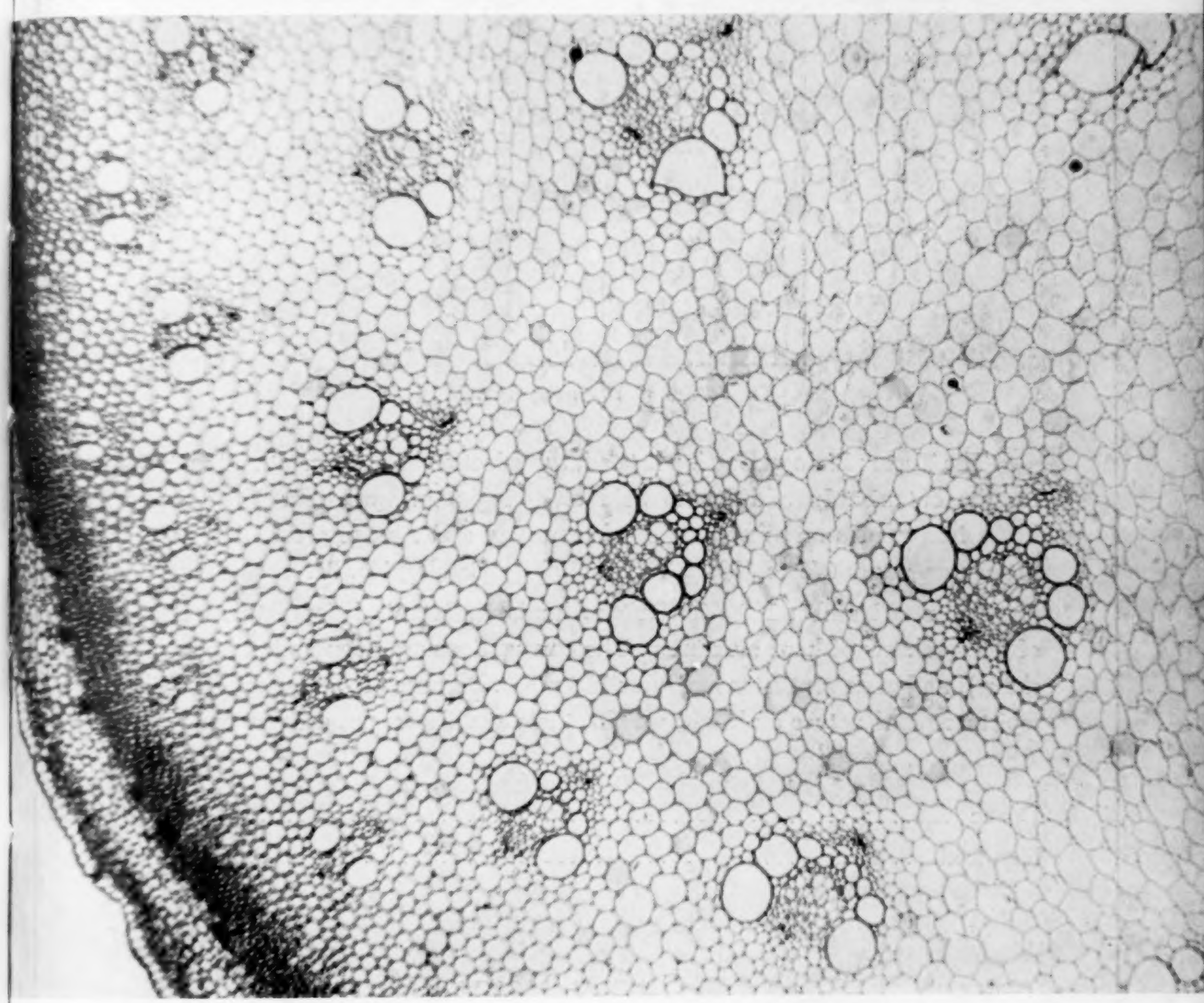
Educ.

The American Biology Teacher

MAY, 1960 VOLUME 22, NO. 5



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Cover Picture

Another photomicrograph from F. Paul Ralston, Biology Department, Ferris Institute, Big Rapids, Michigan. This shows the cross section of a corn stem. It is a valuable mate to the April, 1960 cover picture, showing cross sections of monocot and dicot stems.

THE AMERICAN BIOLOGY TEACHER

Publication of the National Association of Biology Teachers.

Issued monthly during the school year from October to May. Second class postage paid at Danville, Illinois.

Publication Office—Interstate Press, 19 N. Jackson St., Danville, Ill.

Editor—PAUL KLINGE, Coordinator for School Science, Indiana University, Bloomington, Indiana.

The Indiana University address will be the official editorial office.

Managing Editor—MURIEL BEUSCHLEIN, 6431 S. Richmond, Chicago 29, Ill.

Subscriptions, renewals, and notices of change of address should be sent to the Secretary-Treasurer, PAUL WEBSTER, Bryan City Schools, Bryan, Ohio. Correspondence concerning advertising should be sent to the Managing Editor.

Annual membership, including subscription, $6.00; subscription to Journal, $6.00; individual copies $.80; outside United States, $6.75; student membership, $2.00.

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Project Ideas for Young Biologists

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Marywood School, Anaheim, California

During recent years "sciencefairitis" seems to be an intellectual fashion or a "science must" for the developing adult. Since the pressure of educating these individuals and extracurricular work such as science fairs come within the scholastic year, ideas are offered as an aid to more extensive work.

The ideas are grouped in three parts: 1. Project ideas followed by suggestions; 2. A sample technique obtained from *Biological Abstracts* suitable for the advanced high school biology student; 3. Annotated project titles.

The ideas listed carry no guarantee of success as many factors are involved: student interest and aptitude, library references, availability of professional help, time on the part of student and sponsor, etc. To me availability of library references for enrichment of the project material is a major factor.

Students should be taught how to keep accurate bibliography cards, the use of the *Reader's Guide*, *Biological Abstracts*, and the wealth of scientific literature. Careful evaluation and correction of outline and essay are important parts of the organization of the project.

No attempt has been made to compile a bibliography or give specific techniques as such inclusions would destroy the value of library research, individual investigation, and initiative. No project has any value to the individual unless it becomes an intellectual quest.

PART I — PROJECT IDEAS FOLLOWED BY SUGGESTIONS

Study of Ants

1. Construct a formicary. Several may be constructed; one for each species to be observed.
2. Obtain different specimens from the locality.
3. Identify.
4. Make a model of the body of an ant using plaster of Paris for the internal structures and plastic for the exoskeleton.
5. From various bureaus of entomology collect all possible specimens.
6. From research find as many kinds of ants as possible, their habits, nests, habitat, and peculiarities.
7. Make an illustrated notebook of interesting facts.
8. Mount permanently the different body parts for microscopic study.
9. Devise original experiments; i.e., remove antennae, place an ant in solitary confinement, test for regurgitation of food and light perception, observe speed of ant at different levels and at different temperatures, etc.

Struggle for Existence Among Soil Microrganisms

1. Obtain 4 types of soil.
2. Transfer soil dilutions of 1/1000, 1/10,000, and 1/100,000 to nutrient agar plates.
3. Observe antibiotic-producing colonies on these plates.
4. Make Gram stained smears of bacteria.
5. Make pure cultures on agar slants.
6. Make streak plates, incubating for 24 hours at 37° C.
7. Streak known bacteria at right angles to antibiotic-producing colony and incubate at 37° C for 48 hours.
8. Observe.
9. Make streak plates from pure cultures of *Streptomyces griseus* and *Penicillium notatum*.
10. Incubate for 48 hours at 37° C. Observe after 24 hours and after 48 hours.
11. Study all colonies using the Gram stain technique.

Bacterial Study of Milk

Problem—Optimum conditions for keeping coliform count low in pasteurized milk after it reaches the consumer.

1. Obtain raw milk. Refrigerate for 3 hours. Test. Pour a glass.
2. Obtain pasteurized milk. Remove cap and leave uncapped for ½ hour. Refrigerate for 3 hours. Test.
3. Remove cap from pasteurized milk, pour a glass, replace cap immediately. Refrigerate for 3 hours. Test.
4. Control—refrigerate for 3 hours. Test.
5. Show total viable count of bacteria by plating 1 ml. and 0.1 ml. of raw and pasteurized milk on tryptone glucose extract agar.
6. Make colony count.
7. Make total count of coliform bacteria in 1 ml. and 0.1 ml. of the above kinds of milk, using violet red bile agar plates.
8. Incubate plates at 37° C. for 24 hours and 48 hours.

The Effect of Color on Photosynthesis

1. Obtain beakers containing water, green algae, chalk, and fertilizers.
2. Wrap beakers in blue, green, red, and yellow cellophane.

3. Leave one beaker unwrapped as a control.
4. Place all under fluorescent lights.
5. Make macroscopic observations of algal growth.
6. Make microscopic examination of the intensity of green pigment in the cells.

Stream Pollution

1. Study causes, effects, and controls of stream pollution.
2. Add egg white, vinegar, milk, sugar, etc., to individual beakers containing water and some liquid fertilizer.
3. Place algae in the beaker.
4. Place beakers on window sill for several days. Observe. Color and odor will indicate decomposition.
5. Make photographs of the various methods of purifying sewage.
6. Make a methylene blue reduction test on water from a primary sewage tank and water from the final tank. Observe percentage of purity of each.

Protozoan Identification

1. Collect samples of pond water.
2. Fix protozoans and adhere them to the slide.
3. Stain with Giemsa stain and destain. An alternate stain that is satisfactory is basic fuchsin for five minutes, counterstaining in dilute 95% solution of fast green.
4. Make permanent mounts. Better results may be obtained by staining organisms on cover slips.

Protozoan Models

1. Select two examples of each class of protozoans.
2. Study terms, structures, and function.
3. Make plaster of Paris models. Paint and label structures.
4. Explain how protozoans harm and aid mankind.

Beeology

1. Construct a demonstration bee hive.
2. Obtain samples of wax candles, cosmetics, etc., that contain beeswax.
3. Obtain a sample copy of all of the bee journals published throughout the world.
4. Make a miniature model of each kind of bee.
5. Investigate the plants in the locality which are sources of nectar for the bee.
6. Find the scientific names of the plants.
7. Make a collection of the plants producing nectar. Mount and label.
8. Obtain samples of different kinds of honey.
9. Borrow for display purpose the various instruments used in beekeeping.
10. Have for display preserved specimens of queen, drone, and worker.
11. Introduce bees into the hive and make careful observations.
12. Make a map showing areas of honey production.
13. Make slides of body parts, particularly the sting, wings, mouth parts, and legs.

Embryology of the Chick

1. Using Turtox Leaflet No. 17, *Incubation, Fixation, and Mounting of Chick Embryos*, make microscopic slides of 24 hour, 48 hour, 72 hour, and 96 hour embryos.
2. Remove an embryo each successive day thereafter and, after fixation, preserve.
3. Trace the development of any system during the first 12 days of development.

Comparison of Human Blood and Bovine Blood

1. From a standard laboratory text, select 16-20 tests that can be run, some at school and some in a technical laboratory.
2. Run each test at least five times on five different samples of each kind of blood.
3. Tabulate accurately and compare results.

Comparison of Cellular Bodies in Blood

1. Prepare blood smears of 10 kinds of mammalian blood, 3 samples each.
2. Study composition of each kind of blood. Compare cellular bodies.
3. Take photomicrographs.

Histology of the Frog

1. Using a standard microtechnique manual, prepare the various stains required.
2. Dissect a frog, selecting tissues to be used. Use at least 10 different tissues.
3. Dehydrate, stain, embed, section with a microtome.
4. Compare results with those given in a standard histology text.
5. Take photomicrographs.

Cephalic Index

1. Using a meter stick, prepare a suitable instrument for measurement.
2. Tabulate the length and breadth of 100 heads.
3. Calculate the cephalic index.
4. If possible, compare C. I. with I. Q. of the individuals to see if there is any relation.
5. Observe resulting chromatogram using ultraviolet light.

Gallery of Living (State) Scientists

1. Procure the names of scientists, both in industry and in education.
2. Find the biography of each scientist.
3. Write and ask for a picture of the scientist at work in his field of specialization.
4. If possible, interview the scientists personally and observe them at work.

Soil Molds

1. Procure samples of soil from different depths and different localities.
2. Observe the types of soil particles under low power of the microscope.
3. Make a soil suspension in a test tube.
4. Make sterile agar plates.
5. After two or three days, using a wire loop, transfer particles of the soil suspension to the agar plates. Note date of transfer and manner of inoculation.
6. Examine under low power of the microscope drops of the soil suspension for presence or absence of mold spores.
7. Make observations on successive days of the growth of the molds.
8. When the molds are mature, note color and condition of colony.
9. Examine fruiting bodies under high power.
10. Identify, giving scientific name.
11. Test to see if any of the molds are antibiotic in property.

Antibiotics Used Hydroponically

1. Procure antibiotics of various kinds in powdered form from a pharmaceutical company.
2. Obtain seeds of any type. A contrast of a monocot and a dicot is good.
3. Allow the seeds to germinate in a sterile germinating dish.
4. Using sterilized vermiculite, plant the seeds, two or three to a container.
5. Make solutions of varying strengths with the antibiotics and distilled water.
6. Water at stated intervals with a determined amount of solution.
7. Make daily observations of growth, condition of leaves, and color of leaves.
8. Note time when leaves begin to wither or show abnormal changes.
9. At the end of the period of growth, remove the plants and observe the length and condition of the root system.
10. Examine root hairs and root tips microscopically. Variations of the last suggestion:
    - A. Use antibiotics hydroponically and gibberellic acid on the stems.
    - B. Use antibiotics hydroponically but include different nutrients in the vermiculite or in the solutions.
    - C. Same as B but applying gibberellic acid to the stems.

Heart Surgery

1. Explain in detail the structure and function of the human heart.
2. Construct a model of the human heart.
3. Explain literature for the latest techniques in heart surgery.
4. Show by diagram heart abnormalities.
5. Explain, using diagrams and model, the techniques of heart surgery.

Effects of Radiation on Drosophila

1. Obtain stock.
2. Mate three pairs.
3. Obtain F_2 generation, 3 pairs from each original mating.
4. Irradiate with X-ray.
5. Note external variations.
6. Using larvae of the F_2 generation, dissect the salivary glands.
7. Mount and stain salivary glands, making careful observations of the chromosome variations, if any.

Sori of Fern

1. Obtain sori from 10 species of ferns.
2. Select young sori and examine a dissected portion, using stages up to and including young thin-walled spores.
3. Excise small portions of leaf tissue bearing sori.
4. Kill in chrome-acetic solution.
5. Dehydrate soft tissues in alcohol or acetone; tough tissues in butyl alcohol.
6. Stain in iron hematoxylin for nuclear details, in safranin-fast green for general use.
7. Make permanent mounts or photomicrographs.

Gametophytes of Native Ferns

1. Grow gametophytes on nutrient agar cultures, or in porous clay flower pots in a moist chamber.
2. Kill desirable specimens in chrome-acetic fluid.
3. Prepare whole mounts.

Protein Metabolism

1. Procure 15 food substances.
2. Apply the xanthoproteic test for protein.
3. Make a diagram of the digestive system, emphasizing the role of protein digestion.
4. Make linear chemical models of the simplier amino acid molecules.
5. Show experimentally the effect of a lack of protein on an organism.

Graft of Monocotyledons

1. Graft monocots of the same species.
2. Graft monocots of different species.

Study of Lignin in One-Year Woody Stem

1. Collect and identify 15 woody stems of one-year growth.
2. Find scientific name of each specimen.
3. Hand-section each and float in water. Carry

up through alcohols from 15% to absolute alcohol.

4. Dissolve a small amount of aniline in concentrate HCl. Stain and observe.
5. Make permanent slides after staining.
6. Observe and compare the amount of yellow tissue found under the microscopes. This yellow tissue is lignin.
7. Make colored drawings or take photomicrographs.

Salt

1. Procure crude salt, rock salt, and refined salt.
2. Find areas of salt mines and how salt is produced.
3. Using salt solutions of different strengths, find the effect on the tissues of leaves, on protozoans of various species, and on fresh animal tissues.
4. Add salt solutions of varying strengths to foods and observe results.
5. Mount refined salt under the microscope and observe characteristic shape.

Lower Epidermal Variation

1. Obtain 24 leaf specimens, both monocots and dicots.
2. Obtain scientific names from a taxonomy book.
3. Calibrate an ocular micrometer with a stage micrometer.
4. Make wet mounts of the lower epidermis. Tabulate all possible data, presence or absence of epidermal hairs, average number of stomates in a field, presence or absence of accessory cells, shape of epidermal cells, average number of chloroplasts in a guard cell, arrangement of chloroplasts in a guard cell, etc.
5. Tabulate time at which observations are made.
6. Using the technique given in any standard microtechnique manual, make permanent slides of at least ten different specimens.

Chromosomes in Root Tissues

1. Using any standard microtechnique manual as a guide, dehydrate, embed, section, and stain the tissues of ten different roots.
2. Compare length of root growth over a given period of time.
3. Make diagrams or photomicrographs of a single typical field showing mitosis in each of the 10 specimens.

Pollen Germination

1. Select pollen grains from 20 plants. Obtain only mature pollen.
2. Germinate pollen grains in sucrose solution.
3. Make other solutions and observe the effect on the pollen grain, whether the grain fails to germinate, germinates, or is destroyed.
4. Observe time element in growth, length of pollen tube, and position of nuclei.

Comparison of Stigmas and Anthers

1. Dissect the anthers and stigmas of 15 species of flowers.
2. Note the variations, examining under low and high powers of the microscopes. Suggested observations are: presence or absence of epidermal hairs, number of cells composing epidermal hairs, stigmatic fluid, coloration, etc., of the stigma.
3. Macerate the stigma, placing the resulting material in a small amount of water.
4. Study cross and longitudinal sections of the anthers.
5. Try to germinate pollen grain in the substance obtained by maceration.
6. Make macroscopic examination of the anthers and stigmas, noting size in mm.

H_2O, Time, and Temperature Requirement for Germination

1. Obtain 25 kinds of seeds.
2. List common name, scientific name, habitat, type of soil required.
3. Find dry weight of 10 seeds of each kind. Find average weight.
4. Weigh seeds each succeeding day until germination begins. Tabulate results.
5. Record temperature four times each successive day.

Chromatography of Variegated Leaves

1. Obtain specimens of variegated leaves.
2. Macerate each leaf separately.
3. Place in 1% HCl. Note color change.
4. Take juice from maceration and prepare for paper chromatography.

PART 2 — A SAMPLE TECHNIQUE FROM *BIOLOGICAL ABSTRACTS*

Random perusal of *Biological Abstracts* often yields a wealth of ideas for project or research, especially for the student taking an advanced course in biology. The following is outlined from *Biological Abstracts*, 1956, No. 3588, Bhaduri, P. N. and B. R. Majumbar (Indian Agri. Res. Inst., New Delphi), Stain Technol., 30 (2): 93-98. Illus. 1955.

An Improved Pollen Grain Method for Wheat

1. Anthers for 1 hour at 18-20° C in .2% colchicine.
2. Wash in H_2O for 1 hour.
3. Soak in .002 *M* aqueous solution 8-oxy-quinoline at 10-14° C for 1 hour.
4. Wash in H_2O for 1 hour.

5. Fix in Carnoy's solution (alcohol, chloroform, acetic acid-6:3:1) for 6 hours or overnight.
6. Wash in acetic alcohol (1:1) for 10-15 minutes.
7. Wash in 70% alcohol for 10-15 minutes.
8. Wash in water for 30 minutes.
9. Hydrolize in bulk in *N* HCl at 60° C for 10-15 minutes.
10. Stain in leuco-basic fuchsin for 15-30 minutes.
11. Squeeze out pollen grain from stained anther into a small drop of egg albumen smeared uniformly on the slide.
12. Dip slide successively for a few seconds in glacial acetic acid and 45% acetic acid.
13. Place cover glass on smear. Allow a drop of aceto-carmine to run under cover glass. Press gently between folded filter paper.
14. Seal with paraffin. Store overnight.
15. Remove paraffin and separate cover glass in 1:1 acetic acid and n-butyl alcohol.
16. Pass slide and cover glass through two changes of n-butyl alcohol.
17. Remount in balsam.

PART 3 — ANNOTATED PROJECT TITLES

1. Economic plants of a county.
2. Economic animals of a county.
3. Study of *Paramecium aurelium* and the kappa particle.
4. Soil analysis of a sample obtained from every state.
5. Yeast as a feed supplement.
6. Inhibiting protozoans with antibiotics.
7. Bacterial count in milk.
8. Plant tumors.
9. Oral flora.
10. Inhibiting protozoans with disinfectants.
11. Effect of colored light on plants.
12. Mycology of a typical woody area.
13. Stomates in petals, young stems, and upper epidermis of the leaf.
14. Comparative study of hearts.
15. Comparative study of eyes.
16. Pollen analysis.
17. Spore count.
18. Collection of insects on 100 acres.
19. Medicinal plants.
20. Plant galls.
21. Herbaceous plants.
22. Heart-lung machine.
23. Artificial kidney mechanism.
24. Why weed killers?
25. Paleobotany in relation to oil.
26. Nematodes.
27. Treating leather.
28. Miniature filter plant.
29. Vaccines.
30. Cotton fibers.
31. Flax.
32. Diatomaceous earth.
33. Fungi on cereal grains.
34. The purpose of histological stains.
35. Cereals of the United States.
36. Living animal tissue culture.
37. Mushroom farm.
38. Foods as allergens.
39. Pollen of coniferous trees.
40. The production of seed corn.
41. Railroad flora and fauna.
42. Fungi as allergens.
43. Bacteria as allergens.
44. Living plant tissue culture.
45. Biography of a biological scientist.
46. Comparative study of the chromosomes of the salivary glands of ten insect larvae.
47. An original histological technique.
48. Skin grafting.
49. Flora and fauna of five acres.
50. Plankton.
51. Miniature wild life museum.
52. Identification of commercial yeasts.
53. Typing of blood.
54. Hepatitis.
55. Plasmolysis of cells in all tissues of a plant.
56. Effects of colchicine on green algae.
57. Mitochondria.
58. Radiation of seeds.
59. Animal responses to anesthesia.
60. Fossil pollen of a bog area.
61. Effects of vitamin E deficiency on white mice.
62. Chitin.
63. Comparison of starch content of foods.
64. Arteriosclerosis.
65. Sickle-cell anemia.
66. Bone transplants.
67. Thyroid activity in white mice.
68. Response of insects to light stimuli.
69. Comparative study of teeth of mammals.
70. Tranquilizers.
71. Comparative study of cranium and brain in mammals.
72. Resin.
73. Effectiveness of drugs in motion sickness.
74. Microhardness of enamel and dentine of human teeth.
75. Digitalis.
76. Effects of cortisone on tissues of the rat.
77. Survey of infectious diseases of a county.
78. Gerontology of rats.
79. Nutritional requirements for a specific species of bacteria.
80. Diseases caused by fungi.
81. Native ferns of a state.
82. Effect of low temperature control on temperate region economic plants.
83. Economic insects.

84. Mono-crop succession without rotation.
85. Sand dune flora and fauna.
86. Leguminous crops.
87. Plant fossils.
88. Biotic communities in brackish waters.
89. Conservation in a state.
90. Histology of the endocrine glands.
91. Antibiotics as a growth factor in rabbits.
92. Vitamin content of wheat.
93. Soybean analysis.
94. Comparative study of the organs of hearing in mammals.
95. Temperature changes and animal behavior.
96. Environmental effects on stomates.
97. Loss of water from plants.
98. Growth of plant embryos in culture.
99. Anthocyanin pigments of plants.
100. Plant hormones.

Harvey Elmer Stork

March 28, 1890–September 30, 1959

At this time of year when the whole world, or at least much of it, is concentrated on counting its blessings, it is difficult for those who knew Harvey Elmer Stork to realize that the closing year marks the end of the active career of a man who was so highly respected, so deeply admired, and so genuinely honored and loved. Many of us cherished his companionship.

I met Harvey Stork almost exactly one-third of a century ago, and I remember it well. I had returned, temporarily, to Cornell University as a fellow in botany and was introduced to Harvey, a tall red-headed instructor. Almost immediately, we hit it off well together, and in all those years I never remember having any serious differences with him. Particularly do I remember the first and last seminar paper I heard him give, and in some way, they represent my whole impression of his life.

The first serious paper I ever heard him give concerned a review of a paper on the cytology of our common dandelion. It was startling to know for the first time that dandelions could produce fertile fruits without the benefit of fertilization of the egg cells. He presented the story so lucidly that I still remember it thirty-three years later. I was completing my doctorate thesis on seeds at the time, and that seminar paper greatly modified the conclusions I came to a the end of the year. It is discouraging to realize how few modern textbook writers and teachers working with precollege students ever heard of the idea. Certainly there are more students today who misunderstand dandelions than there are those who know the story Stork presented to us that day.

The last seminar paper I heard him give was wholly facetious and was presented at a graduate student party after we had each seen service in World War I. It was just before the privately supported Arts College Botany Department at Cornell was about to surrender its leadership to the tax-supported Botany Department of the Agricultural College. Harvey presented tables which he claimed he had prepared based on the number of rats he had observed over the years in the herbarium. He presented graphs to support his views and advanced the idea that since the number of rats was steadily on the increase, and since it was a well-known fact that rats always desert a sinking ship, it was obvious that the Arts College Botany Department was destined to survive. All of us knew, only too well, any argument based on such evidence was not sound as events proved, of course. The point is that Harvey Stork could be effective as a serious scholar and as a fun loving member of a group.

Harvey Stork believed in getting a sound training for his career. In 1914 he received his A.B. degree from the Indiana Normal School at Terre Haute, Indiana. In 1915, he took a Master's degree in Botany at Indiana University, and in 1920, he took his Doctorate in Botany at Cornell University. His graduate career was interrupted by two years of service as a sergeant in the photographic section of the Air Force during which time he saw service in France. At the end of the war, he spent four months on his botany at the Sorbonne. Even after he had his final degree Stork continued to grow in his chosen field. He served as a ranger naturalist in the National Park Service in the West in 1927, 1929, 1934, and 1935. He worked in Central America during the summers of 1920, 1923, 1928, 1932, and during the year of 1938-39, was second in command of a University of California botanical expedition into the Andes.

Stork's researches centered around the flora of Peru, the anatomy of woods (particularly those of Central America), the cytology of fungi, the role of lithium in plant nutrition,

and the genetics of the genus *Taraxacum* to which the dandelion belongs. He was respected as a member of significant professional groups of his field of interest. He was a Fellow of the American Association for the Advancement of Science when that title meant more that it seems to at present. He was a member of Sigma Xi and Gamma Alpha, scientific honorary societies, and was listed in *Who's Who in America* and *American Men of Science.* He held membership in the Botanical Society of America, the Torrey Botanical Club, and the Explorers' Club. He was one of the founders of the Minnesota Academy of Science and in 1933 served as its first president. According to Mrs. Stork, his most favored organization was the National Association of Biology Teachers of which he was the fourteenth national president, serving between the administration of Dr. Richard Weaver and Dr. Leo Hadsall, and playing an important part in identifying the organization with the American Institute of Biological Science.

Harvey Stork had a wide and effective teaching career. He taught both elementary school and secondary school classes in his native Indiana. He served three years as instructor in botany at Cornell University. His longest career in teaching at one institution began in 1920 after receiving his doctorate. This was at Carleton College in Minnesota where he was assistant professor of botany from 1920 to 1926 when he became professor of botany there and served as chairman of the Botany Department and as director of the Arboretum. He retired from Carleton in 1955. At his death, the Carleton College faculty summed up Dr. Stork's career there by stating that "He was an unusually successful classroom teacher—one who combined in the happiest way high standards of scholarship, great enthusiasm for his chosen field of botany, and a warmly human personality that endeared him to all students who worked with him. He was the complete and dedicated teacher. Carleton faculty colleagues . . . knew and loved and respected this man for the steadiness of his purpose and for the friendly, unassuming competence with which he filled his role. . . . They cherished his whimsical wit and optimistic philosophy of life. . . ."

Following retirement at Carleton, Dr. Stork spent the year 1955-56 collecting tropical woods in Costa Rica, and the following year, as a research associate, he spent studying these woods at the University of California at Berkeley. Working under a John Jay Whitney award he taught botany in 1957-58 at Tongaloo Southern Christian College in Jackson, Mississippi. The following year, supported by Federal funds, he worked with an institute for high school science teachers at the Iowa State Teachers College at Cedar Falls. In the fall of 1959, he accepted appointment for a year as head of the Botany Department of Tongaloo. Two weeks after beginning this work, he died of a heart attack on September 30, 1959.

Dr. Stork was the author of "Studies in Plant Life," and of "Evolution of Plants," and was coauthor of "Phytogeography of Peru," and of "Plant Hunting in the Andes." Few workers in what is known as the science education field can match the record left by Dr. Stork as a teacher and researcher in basic science at a wide range of academic levels and over a wide geographic and time range. The National Association of Biology Teachers did well to recognize him by electing him as one of its presidents.

Harvey Stork was a Methodist. In 1922 he married Gertrude Coffeen. They had two children. Their son, Dr. Donald H. Stork, is a professor of nuclear physics at the University of California in Los Angeles. Their daughter is Mrs. Paul Stillwell of Granby, Connecticut. They have eight grandchildren.

We recommend that by resolution and by publication in "The American Biology Teacher" we express our appreciation of what this man did for the National Association of Biology Teachers and for science teaching generally. We recognize that his death is a great professional loss and that those of us who knew him well lost an exceptional friend. For what it may be worth, we extend our complete sympathy to his relatives and to friends who may have been more closely identified with him than have we.

E. LAURENCE PALMER

Free Literature

"Closing The Gap," a ten page selected bibliography on science, education, and careers for the science and engineering student is available free of charge from the Scientific Apparatus Makers Association, 20 North Wacker Drive, Chicago 6, Illinois.

Editorial

The Biology Course—When to Teach It?

In many schools and in many written statements, biology as a ninth grade subject is being advocated. From an informal poll of the NABT Board during the AAAS meetings and discussion with many teachers there appears to be lack of agreement as to whether this is good or bad for numerous students. Most biology teachers are willing to consider the possibility and its effects. The difficulty which is appearing, and about which I am becoming concerned, is that the shift is being made widely without any basic information on what happens to the student and the course with the change in level. Shifts are being made as permanent changes, not as experimental moves. When we have no basis for knowing the results, do we want this long-term commitment?

In many school systems biology has been considered a ninth grade subject for some time. Studies of the biological understandings, the continued interest in biology, the additional science taken by these students as compared to students where biology has been a tenth grade subject might give some sound placement guidance. But as far as I know, no such studies have been undertaken. Further, the pressure to do something about the science curriculum is so great that administrators cannot wait for the results of such studies. Is this sound curriculum planning?

The impetus for changing biology in the past few years stems from a report of a committee that made a study of the science program in the state of Illinois. In this report the statement is made that since most general science is biological, a basic premise to their proposal with which my own experience disagrees, the usual general science should be condensed into the seventh and eighth grades and biology given at the ninth grade. A physical science class is suggested for the tenth grade. Inconspicuously, it is suggested that the sequence of the courses might be reversed. This latter suggestion has been overlooked in most of the later statements based on these recommendations. The joint committee on science curricula of the AAAS and the AACTE included this report in their discussion and informal recommendations. One of the last reports of the President's Committee on Scientists and Engineers is an outline of science and mathematics curricula that recommends ninth grade biology and tenth grade physical science. Because of the status of these last two groups particularly, administrators have received much publicity about the suggested changes, have accepted them as authoritative, and have proceeded to make plans for changing local curricula, often without consulting the local teachers involved. Because of the publicity spotlight on the teaching of science, community leaders have begun to be concerned. Demands are being made of administrators to answer this concern. The easiest changes are simply to shift the courses around and thus appear to have met the problem. Is this the way to a sound curriculum?

Most biology teachers who favor ninth grade biology do so because this allows the possibility of an "advanced biology" at the senior level. This is good. I would be interested in knowing how many of the science-oriented students do take advanced biology rather than additional physics or chemistry where all are available. It seems to me that the recency of the experience with the physical sciences and their greater challenge because they can be taught at a more mature level will tend to draw the able students away from advanced biology when there is a choice offered. So before a biology teacher sells his birthright to students with at least the maturity of tenth graders, it should be very clear for what course room is being made. I know of one community where the able ninth graders were given biology, took, or are taking, chemistry and physics. As of the beginning of the current school year it was still undecided what senior course should be made available to them. Is this the sort of integrated curriculum that we talk about and find desirable?

I would like to raise a question concerning the proposal by some that when biology is moved to the ninth grade a senior biology be required of these able students. Why teach two courses? If the biology is to be required why not have a single course with chemistry

and physics as prerequisites? A course of this type, taking advantage of the additional background of the student, can catch and challenge students who have not been challenged by our usual biology course. I know of an able student who was unable to take biology as a sophomore. He was allowed to take it as a senior following physics and chemistry. He found the biology extremely interesting, fascinating, but was unable to comprehend how the rest of the class could really understand the material without any physics or chemistry. Is not this the basic challenge to biology teachers in regard to able students?

I doubt that anyone will question that a biology course can be taught to ninth graders with success, or that ninth graders can do as well as tenth graders in many cases and with many types of courses. But there are questions that I would like to raise—loudly and long. Is this the biology that we want the potential scientist to have? Is this the biology that will give the student a picture of the field and activities of modern biology? Is this the biology that will challenge and intrigue him, will make him a biologist? As teachers of biology, and curriculum planners, we need to take a hard searching look at the content of our courses. Are we, as the teachers of the subject, being fair to our field? From what I know of the content of the AIBS filmed biology course, and from the discussions concerning the BSCS, I feel that the question of the grade placement of biology may assume a totally different picture when these programs become widely available. These are modern biology courses reflecting the trends of current research and interests of biologists. I am convinced that if teachers sincerely try to develop the material included in these programs the need for student maturity and physical science background will become so obvious that the question of moving biology to the ninth grade, even for the able students will no longer be raised. In the meantime, I hope that biology teachers who have a voice in curriculum planning will be sure that promises of advanced biology and pressure for any change do not place them in a position where further change will be difficult or impossible for a long time.

One of the most promising moves with which I am familiar is appearing in some local curriculum thinking. The assigning of a course to a certain grade level is being questioned. The thinking is turning to analysis of the prerequisite ideas. If to understand biology the ideas of physics and chemistry are needed, the possibility of taking these courses before biology is built into the program. But certain levels of mathematics competency are needed for physics as it is taught. This means that the mathematics and science curriculum planners must integrate their thinking. In an increasing number of communities, the suggestion for a ninth grade physical science class is being seriously considered as the compromise answer to the problem of the mathematics needed for physics and the need for physical science concepts to precede the biology class. In this course are included the physical science principles that are basic to and often included in each of the special science courses—the structure of matter, basic energy relations, basic chemical processes, the gas laws, etc. With the potential changes in the math curriculum, the necessary math will probably be known. However, most of the planning with which I am familiar is for a course that is more concerned with the principles on the qualitative conceptual level than on the quantitative level. Following this course, the student would be free to elect the special sciences in any order which he chose. Thus any implied prestige sequence would be eliminated. In time students would tend to do their own grade placement.

We are working in a period when science is receiving unprecedented attention but when biology does not seem to rank as a science in some situations. Let us not as teachers of biology make less demands for our field than do the other sciences! Let us do all we can, any place we can, to improve the general understanding of the value—but also of the complexity—of the principles with which we deal. Let us not sell ourselves and our subject short by being willing to eliminate some of the more complex aspects. Let us teach a biology course that reflects the real extent of the contributions that biological research has made to our lives and living. This is my plea when the problem of grade placement is faced!

DOROTHY MATALA,
NABT Representative on
AIBS Board of Governors

Research in High School

ARTHUR J. BAKER and LEONARD G. SCHEEL
Crystal Lake Community High School, Crystal Lake, Illinois

Last year 36 superior students gave 1410 student hours of work on a research problem. They gave this time freely, without diminution, without credit, without pay. They worked as hard for science as the varsity squad did for football.

This receptive attitude toward work in science was motivated by a grant, one of eleven such grants offered in the nation, from the U. S. Department of Health, Education and Welfare. The grant approved a research problem on the hypothesis that high school students might derive measurable value from work with basic research. If successful, it is their hope that some national society or agency would then establish a national program of such efforts.

Although the two teachers who were presented the grant embarked on this experience with optimism and enthusiasm, they, nevertheless, had not anticipated the extent and depth of impact that this problem has had upon the students involved.

But it takes more than student hours and enthusiasm to be of lasting value, and this story will attempt to impart to the reader why this program deserves such merit.

The teachers involved, in an attempt to establish an hypothesis, asked themselves questions such as:

> Will the growth inhibition factor of vitamin A deficiency be overcome or altered in the presence of an excess of a growth stimulating factor?
>
> Will a rat under pituitary growth stimulation be so conditioned as to show pathological signs from a deficiency diet that would not otherwise appear?

Discussion of such questions led to the formation of a tentative hypothesis which might be stated as:

> "Rats, stimulated by anterior pituitary growth hormone, overcome the growth inhibition factor of vitamin A deficiency, and show more clearly the pathological symptoms of the vitamin deficiency."

And so to work. All experiments were begun with 24 day old white female rats of the Sprague, Dawley strain. All rats in each experiment were fed the standard USP Vitamin A deficient diet. Groups of rats were subjected to concomitant variables of Vitamin A per 1,000 grams of body weight, such as:

Group A	0 units
Group B	50 units
Group C	100 units
Group D	400 units
Group E	1,600 units

Each group of rats were then subdivided into groups, half of these receiving no growth hormone, and the other half receiving two rat units of anterior pituitary growth hormone subcutaneously, daily.

Four work groups, each comprised of 3 or 4 students, were formulated. Work Group I began its duties at 7:30 a.m. when they donned their lab coats and face masks and proceeded with the seemingly unpleasant task of cleaning the "catch-all pans." This was immediately followed by the animals being fed vitamin A with the aid of 1cc tuberculin syringes equipped with ball tipped needles. The hormone was also administered in the morning. Each rat received 2 rat units of pituitary growth hormone; one unit in the morning and one after school. These tasks completed, the counter tops and floor were mopped, and it was time for the first class.

Work Group II devoted their lunch period to research. Their duties involved a complete external observation of each animal. At the onset of the problem, the students developed a daily report sheet on which they incorporated a check system to facilitate recordings. Three associates worked cooperatively as a team checking each other's observations of weight, eyes, teeth, coat, feces, nostrils. This group also recorded the data on permanent record cards and charted the weights on permanent graphs.

The third work group took over immediately after school. Again one unit of growth hormone was administered.

These students were now deeply imbued with the principle that science is not romantic glamor and tinsel as were their thoughts when

Each time an animal is weighed, the results are checked by a person other than the one doing the weighing. Here Mr. Scheel checks, as Carol weighs a rat. (Photo by Del Cryer.)

they came to us. They had developed a scientific attitude. Perhaps even as important was the development of an appreciation for, and skill in, problem solving. In this regard evening sessions proved most rewarding. Questions such as: can we test whether or not a rat is hearing well; are rats right or left pawed; how can the heart beat be accurately counted; and others were presented and solved with ingenuity and intelligent application of logical reasoning to a problem in science.

Some conclusions from the work of last year follow:

The anterior pituitary growth hormone works independently of Vitamin A.

The minimal amount of Vitamin A necessary for a normal development is somewhere between 400 and 1,600 units per 1,000 grams of body weight per day.

Rats are not right or left pawed.

Vitamin A deficiency slightly lowers the rate of heart beat.

Vitamin A deficiency results in a marked whitening of the teeth, which are normally yellow.

The growth hormone factor compensates for the retarded growth factor of Vitamin A deficiency. Thus a rat on a normal amount of Vitamin A without growth hormone reaches about the same size as a rat on no Vitamin A, but 2 units of growth hormone. In spite of this correlation, these two factors are independent of each other.

A few of the benefits to the students may be stated now.

A new dimension of the understanding of scientific methods dawns. Terms such as hypothesis, control, concomitant variable, are not something to be memorized and parroted back to the teacher, while deep down some of them think of it as gibberish nonsense. Rather, they are terms used in conversation when setting up a phase of the problem, and in turn actually applied to the problem. They no longer look at the methods of science but look through them.

Ron looks on as Mr. Scheel checks Roger and Carol's recording of data in the permanent records. (Photo by Del Cryer.)

The students coming to us are literal minded. Science, to them, is the discovery of the vacuum tube or to make a radio. Science is the discovery of the Salk vaccine to cure polio. They are forced by an inner compulsion to apply everything. They have no conception of the term pure science. The idea of a search for truth for truth's sake is to them impractical, unrealistic, nonsense. How shall one correct this thinking? Have them work with science. Then, will they experience just a

A comprehensive observation sheet is filled out for each animal daily. Mr. Baker looks on as Joanna observes and Julie records. (Photo by Del Cryer.)

mite of the thrill of discovery. Then they understand.

Superior students have an intellectual dignity too seldom tapped. When working with a research problem they are allowed to let their minds come to grips with tough problems. From this is gained new self esteem, new respect from fellow students, and new humbleness through failure. Students with this kind of experience often show an increased maturity.

With all our efforts to upgrade science teaching, and all the millions of dollars spent to improve the job we are doing, why hasn't this been tried before? And the plan is based on the simplest principle of learning. How can we best teach the superior student what science is all about? Have them learn by doing!

Lucky Strike for Education

G. E. CARAKER
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For over two years I have been sending fossil specimens to schools, colleges, universities, clubs, private collectors, and museums all across America and Alaska. In addition to local or national requirements, six countries are also on the mailing list, with one somewhat unusual request coming from a graduate student connected with the Soviet Academy of Sciences in Moscow. He was doing work on a certain species of fossils, and he indicated that he made periodic trips into Siberia. I refer to this because I had hoped to create a system of exchange whereby he would get fossils from North America, and our schools would have the rare experience of getting their hands on fossils from Siberia, an area which has proved a happy hunting ground for scientists for many years. While I failed in my effort to get Russian fossils, and since he was unable to send any money, the barter system found me the recipient of the complete works of Pushkin, and an English-Russian Dictionary. Another unusual order came from the Frei Universiteit, located in the western zone of Berlin. I visited the University several years ago little realizing that I would be sending fossils to that science department.

A fossil is any material evidence of ancient form of plant or animal life, or one might put it this way: that a fossil is the preserved remains or mineral replacements of living things of previous ages; for example, a piece of petrified wood is a fossil, for while it has changed its chemical organic composition, it has nevertheless retained its shape; in fact, petrified means turned to stone.

And the bonanza of fossils now being enjoyed by so many of our science students would perhaps never have come about if it were not for the fact that I had accepted a faculty position in northern New York. I wanted to be near the famed St. Lawrence Seaway project, and I had some personal plans that required my attention across in Canada.

One late afternoon, dusk, some would say, I went for an aimless stroll into a glorious sunset. It was unusually vivid, and as a result I stumbled and fell over a small outcropping that had been deposited and buried there by the giant excavation equipment of the construction company busy with the creation of the Seaway at that particular area. Something caught my eye. It looked like the impression of a shell. I examined it quickly to find that what I had fallen over was a section of a system of rocks deposited during the paleozoic era which flourished about 400 million years ago. I discovered myself among tons of rock embedded fossils. There were brachiopods, exclusively marine animals that covered their soft bodies with shells made of two parts—they look like a small mussel—and there were trilobites, meaning three-lobed, consisting of the head, body and tail. They were among the earliest and most widely known of fossils—and much sought after, and here I sat among a fortune of them which schools and colleges all over America, in fact the world, would be happy to have among their science collections.

Fossils aid the teacher in presenting no fewer than ten courses at the junior and senior high school level as well as at university and college level. Industry uses fossil specimens as a guide and index in their search for oil de-

posits. Fossils, in fact, furnish the chief means of comparing the relative chronological value of a group of rocks.

Soon, I had written to schools in various parts of the country, suggesting that they participate in the science venture by indicating whether they would care to have a package of fossils. The results were beyond expectations. The costs to those who requested a package of specimens consisted of expenses incurred in transporting the loads from the excavation site to my basement, plus packaging and mailing charges. One school insisted on having two packages of the "scientific stake in the Seaway." Schools and colleges in the south were far ahead of schools in the north in the number of requests. Kansas led the national field by far.

South Africa and the United Kingdom outclassed others in interest, and the British Museum, even went to far as to assist in the proper identification of the specimens, as did our National Museum in Washington, D. C. and the Museum of the State University of New York. Four weeks after sending fossils to schools overseas, a science exhibition in Natal, South Africa, included a display of fossils from the ancient river beds of the St. Lawrence River and the Long Sault Rapids.

Soon the inevitable phase in situations such as fossil requests developed—the aspect of international exchange. I was able to secure for some of our schools the much sought-after famed leaf fossil glossopteris, which once flourished only in scattered parts of Southern Africa, Siberia, and Eastern Europe. And at the time of writing I am looking forward to receiving some industrial diamonds from South Africa in exchange for fossils from northern New York.

Since the day of that lucky walk at dusk, I have sent about four tons of fossils to those parties expressing an interest in the enormous unusual science project. But the work was brutally hard. While the Canadian Government provided men and equipment to some teachers, and students, I was forced to go it alone.

Not only did the discovery assist our science program, it brought a new light of information to the construction workers who would leave their jobs and say something like this, "you all right, Mac?" or "what you looking for, old man?" It took just a few moments to explain. I would pick up a piece of rock-embedded fossil and say, "see that shell shape there? Well, we need this rock for our schools and colleges all over America so that we can help push this science program which has bogged down for so many years."

It was a great satisfaction to me to feel that I was opening up new horizons of interest to men who had never before perhaps seen or even heard of fossils. And soon I had seminars, one might call them, out there in the field, among dried river beds, many millions of years old. I shall never ever forget the look on the faces of those men as they took advantage of this new realm of informal education. I had my lunch with them, and more than I can ever record, they assisted me in finding what I was seeking and aided me on many occasions in moving large chunks of bedrock to the dilapidated car I bought especially for the purpose of transporting the specimens to my basement laboratory. In the basement I would don goggles, gloves, and an apron and set to work. First the fossil chunk would have to be broken to a certain size, then weighed, then scrubbed in hot water and soap, and then dried over a hot gas stove. Finally, I would spray the fossil with a chemical, creating a hard transparent membrane of protection.

The river beds are long reflooded, and the rock fossils once exposed to man for the first time in recorded history are again held in secrecy and discipline by the mighty St. Lawrence River and the Long Sault Rapids. For a brief moment in geological history scientific treasures were made available. I am sure that students in schools all across America and in other parts of the world are enjoying the results of an accidental scientific discovery in upper New York, U.S.A.

Conservation

A new land conservation group has been incorporated in Allen County, Indiana, to acquire and preserve natural areas for scientific, educational, and public recreational purposes. According to Dr. John W. Klotz, the first president, the purpose of ACRES will be to acquire land which will be held by the corporation for public benefit. Dr. Klotz is Professor of Natural Science at Concordia Senior College.

A "Natural" in Nature Study

RICHARD F. THAW
San Jose State College, San Jose, California

More often than not the very last day of the school year; i.e., the last full length day, is anything but soothing to either pupil or teacher. The year's work has been completed, the last test has been taken, returned and discussed, and the room has been put into order for the summer. It's a day that can drag—too often pupils will not care for further enlightenment, and the day can develop into a colossal bore unless the pupils are, and here's that word again, *motivated*. Of course, motivation comes easy in biology, but there are times—times that little "tricks of the trade" can do wonders. Many teachers have used the old dodge of having pupils compete in the spelling bee manner, and it can be successful both as entertainment and as education. A little device that will make the last day a profitable one is a contest related to the spelling bee contest, but competition is between classes; i.e., between biology classes of different periods of the school day. It is a contest in which the answers to the quiz are not given out until *the end of the school day*—only the score (fewest points missed) is given to each class at the conclusion of their period. These scores are entered on the chalkboard in such fashion as follows:

PERIOD 1—*5*
PERIOD 2—*3*
PERIOD 3—*4*
etc.

The contest involves animal or plant "inventions" that are akin to man's inventions. Placed on the chalkboard are two lists—one is a numbered list of inventions, the other an alphabetized list of organisms. The rules of the contest allow pupils to volunteer oral suggestions as to how a given item should be matched with some specific organism. At each suggestion, the teacher so marks on the board the suggested letter on the line in front of the chosen number; e.g., *Q17*. After the class is finished then the teacher examines the completed test and announces the total number wrong, if any. Only after the class has worked out *several* changes does the teacher again announce the number wrong. This obviously prevents too many clues as to which specific answers are incorrect. The amazing thing that will happen, if the teacher has been a good salesman, is that pupils *will* come in *after* school that day to see how their classes compare and find out the answers to the quiz. By this time the chalkboard reveals class standings and a properly matched test. Would you like to try your hand at a little matching game? Place the letter of the organism in front of the appropriate number.

1.—water skier	a. old world chameleon
2.—diving bell	b. drone fly larva
3.—snorkel	c. moon snail
4.—animal pit trap	d. water spider
5.—revolving eye-piece	e. scallop
6.—pistol	f. hydra
7.—fishnet	g. shrimp
8.—harpoon	h. shrew
9.—cymbals	i. sea cucumber
10.—sandpaper	j. shark
11.—thermometer	k. land spider
12.—balloon	l. sunfish
13.—whiskbroom	m. cricket
14.—drill	n. ant lion
15.—wheel	o. rotifer
16.—heliograph	p. antelope
17.—fly paper	q. toxotes fish
18.—antiaircraft fire	r. sundew
19.—hypodermic needle	s. rattlesnake
20.—piston & pump	t. leech
21.—air conditioning	u. honey bees
22.—lasso	v. bolas spider

By way of explanation, a word or two about each of the organisms needs to be said.

OLD WORLD CHAMELEON—You'll remember from a Walt Disney Film this animal's ability to revolve its eyes (almost turret-like) independently of one another. It may be a bit far fetched to liken it to the revolving objectives of a microscope but the kids will accept it in good grace.

DRONE FLY LARVA—Sometimes called a rat-tailed maggot because of its telescoping breathing tube.

MOON SNAIL—This organism has a dandy

drill in its many-toothed radula—a tongue for boring holes in bivalves.

WATER SPIDER—There are lots of different "water spiders," but we're thinking of the one that carries air bubbles beneath the water surface and releases these bubbles under a web in sufficient quantity to provide an airy underwater house.

SCALLOP—Ever watch a scallop move? The similarity to the coming together of cymbals is clear to those of us with imagination.

SHRIMP—Lots of kinds of shrimp in the sea and among these is the pistol shrimp which stuns its prey with the snapping noise of its claw—a claw functioning somewhat like a cocked hammer on a hand gun.

HYDRA—Who in biology hasn't heard or even seen the nematocysts or "harpoons" of hydra?

SHREW—Many writers report having seen the little water shrew skipping along the surface of a small pond—little water skier?

SEA CUCUMBER—This fellow is remarkable—he can spit out his respiratory "tree" and ensnare small animals in its sticky length—a peculiar defense mechanism this "fishnet."

SHARK—The placoid scales of this fellow would and sometimes do make a rugged sort of sandpaper.

LAND SPIDER—Scads of different land spiders, and many of them spin lengths of silk, which caught by the wind, balloon these animals from one place to another—this can account for the spider webs you sometimes feel on your face as you walk to school in the autumn.

SUNFISH—Many's the fisherman that has seen the male sunfish use his tail as a whiskbroom in forming the depression in the sand on the creek bottom that is to be the "nest" in which the female sunfish will lay eggs.

CRICKET—Count the number of cricket chirps in 14 seconds and add 40 and you'll have the temperature.

ANT LION—Who has not been fascinated when watching an ant fall into the ant lion's pit?

ROTIFERS—or "wheel bearers" with their crowns of cilia could represent the action of a rotating wheel.

ANTELOPE—When alarmed, up goes this animal's tail and the sun's reflection on the white rump makes a fine warning device—a kind of built-in heliograph.

TOXOTES FISH—The squirting fish whose "anti-aircraft fire" knocks flying insects into the water was for years considered a hoax before these fish were kept in captivity.

SUNDEW—A plant that is a living fly trap. Not only are its leaves sticky, but the plant exhibits remarkable motion in response to touch.

RATTLESNAKE—I guess you could say that the fangs of this creature function in a way similar to that of a hypodermic (below the skin) needle.

LEECH—What an efficient little bloodsucker this is. Built-in piston and pump can fill his belly in a hurry.

HONEY BEES—For eons these busy little creatures have had a most practical air conditioning set-up in the hive. Man certainly has learned lots of tricks from observing animals.

BOLAS SPIDER—An animal which has a trick of swinging a long thread of silk with an enlarged (and odorous) ball on the end of it. Moths are attracted to this structure and, upon touching it, are stuck fast. Spider then drags the hapless prey into its clutches—not too far removed from the principle of the lasso.

Well teacher, you do a good job of selling a product, and you and the students can have a most enjoyable "last day of school."

Scientific Apparatus

Kenneth Andersen of the Scientific Apparatus Makers Association estimates that the United States expenditures for research and development, including the government's outlay, may hit 12 billion dollars in 1960. He states that the major portion of instrument sales today are products which were not in existence before World War II. About fifty per cent of the instruments on the market today came into being within the past few years. Many of the high standards of quality and uniformity demanded of products today can only be achieved through the use of automatic process control instruments.

The Bluegill

"The Bluegill," Publication 230 of the Wisconsin Conservation Department, Madison 1, Wisconsin, has just been published. It tells of the Bluegill's life history, ecology, and management.

Laboratory Observations of the Anatomy of the Snake*

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GILBERT L. DEHNE
Elston Junior High School, Michigan City, Indiana

The position of the internal organs of the snake indicated in this guide is based upon the examination of eighteen snakes. For the benefit of the tenth grade student reference is made to positions of organs by use of fractions to refer to approximate distance from tip of nose to the vent of the snake. Occasionally, size or distance is referred to in inches.

For the benefit of the teacher or students interested in any special work with snakes, there are two tables submitted. In this table the organs are located with reference to the ventral scale (scute) number. Therefore, any student who wishes to perform a thyroidectomy, for example, on one of the species listed here, might locate the thyroid without making a huge incision and perhaps making it entirely in the wrong place.

Snakes dissected during the preparation of this guide were:

a) *Three* banded water snakes, *Natrix sipedon pleuralis*, collected at Lake Stahl, Brown County State Park, Indiana.

b) *One* banded water snake, *Natrix sipedon* ?, collected near Linton, Indiana. The sub-species was not determined but may be an intergrade between *Natrix s. sipedon* and *Natrix s. pleuralis*.

c) *Seven* yellow bellied water snakes, *Natrix erythrogaster transversa*, collected in Saline, Stafford, and Neosho Counties in Kansas.

d) *One* copperhead, *Agkistrodon contortix mokeson*, collected in Lilly Woods northeast of Bloomington, Indiana.

e) *One* chain king snake, *Lampropeltis getulus getulus*, found on Highway 46, ten miles east of Bloomington, Indiana.

f) *Three* western diamond back rattlesnakes, *Crotalus atrox*, collected in Woods County, Oklahoma.

g) *One* prairie rattlesnake, *Crotalus viridis viridis*, collected in Woods County, Oklahoma.

h) *One* blue racer, *Coluber flaviventris flaviventris*, collected in Saline County, Kansas.

Morphology

A. Reptiles in general possess all the general features of vertebrates.
   1) Bilateral symmetry.
   2) Skull and backbone housing a tubular nerve cord which expands into a brain.
   3) Eyes, ears, and nose.
   4) Heart with a closed circulatory system.
   5) Regular set of viscera.
   6) Usually paired limbs or rudiments.

B. Plus these special features.
   1) Poikilothermy or "cold-blooded."
   2) Lungs—as a rule they never possess gills like fishes or amphibia larvae.
   3) Most are covered by scales or scutes which are almost waterproof.
   4) Large amounts of yolk in eggs which are laid on land.
   5) Hatch essentially similar to the adults.
   6) Septum which partially divides the ventricle and aortic trunks.
   7) Only a single ear bone (stapes) as compared to three in the human.
   8) Several bones in the lower jaw as compared to a single bone in other vertebrae.

Morphology of Snakes
(Sub-order Serpentes)

1) No limbs—with a few exceptions, all traces of limbs and girdles, sternum, and abdominal ribs are lost. Python has a rudimentary pelvic girdle. The rudiments of the hind limb (larger in male) are thought to stimulate the female during coitus.
2) No external ears but there are internal ears.
3) No eyelids and no tear glands.
4) Backward slanting teeth which are continually replaced as they are worn out.
5) Halves of the lower jaw not fused.

*Most of this work was done by the authors during the Summer Institute for Teachers of High School Biology at Indiana University in 1958.

6) Box-like brain case protected underneath by a rather massive parasphenoid bone.
7) Upper jaw somewhat loosely fastened to the cranium where there is some movement.
8) Numerous vertebrae with attached true ribs. These are not fastened loosely together as the movement of a snake might lead you to believe. Since there may be as many as 300 vertebrae, the individual bones do not have to move very far to insure flexibility.
9) Modified viscera.
10) The formation of the head jaws, esophagus, and ribs all contribute to the ability of the snake to eat large pieces of food.

I
Laboratory Observation

I. OBJECTIVES
   A. To make observations and comparisons.
   B. To encourage the concept of functional anatomy.
   C. To improve skill in handling instruments.

II. EQUIPMENT
   A. Anesthetics.
   B. Mounting materials.
   C. Dissecting materials.

III. PROCEDURE
   A. Killing the snake.
   B. Making external observations.
      1. Color pattern.
      2. Scale comparisons.
      3. Features of the head (eyes, nostrils, shape, etc.)
      4. Mouth parts.
      5. Maneuverability of the lower jaw.
      6. Secondary sex traits.
   C. Making internal observations.
      1. Exposing the parts.
      2. Locating organs without disturbing any parts.
         a) Windpipe.
         b) Esophagus.
         c) Thyroid.
         d) Heart.
         e) Liver.
         f) Gall bladder.
         g) Fat bodies.
      3. Locating other organs by use of probes to move parts aside.
         a) Lung.
         b) Stomach and intestine.
         c) Spleen and pancreas.
         d) Testes or ovaries and adrenals.
         e) Hemipenes.
         f) Kidneys.
         g) Peritoneum.
      4. Making additional observations by actually removing certain parts.
         a) Pyloric sphincter.
         b) Longitudinal folds of esophagus.
         c) Pituitary.

II
Laboratory Observation

I. OBJECTIVES
   A. To enable the student to observe the results of evolution in the arranging of the usual vertebrate organs in an animal without the usual vertebrate contour, thus promoting the concept of *functional* anatomy.
   B. To show that snakes are definitely sexed though there are no basic secondary sex traits to indicate this.
   C. To provide opportunity for the student to observe whether the snake is truly "slimy."
   D. To provide additional experiences in the handling of dissecting instruments.

II. EQUIPMENT NEEDED
   A. Anesthetics (for large groups, this will be done by the teacher.)
      1. Cotton.
      2. Fruit jar and lid.
      3. Ether.
   B. Mounting for dissection.
      1. 1 by 6 softwood board 3 ft. long.
      2. Thumb tacks or straight pins.
      3. Three-penny nails.
   C. Dissecting.
      1. Dissecting kit (scissors, forceps, scalpel, needles, probe).
      2. Cotton (to soak up blood and other body fluids).

III. PROCEDURE
   A. Killing the snake.
      1. Place snake in a jar large enough for the snake but small enough that a minimum of ether may be needed.

Table I

	THYROID	HEART	LIVER	GALL BLADDER	SPLEEN	PANCREAS	RIGHT KIDNEY	LEFT KIDNEY	RIGHT TESTIS	LEFT TESTIS		RIGHT OVARY	LEFT OVARY	VENTRALS CAUDALS
Natrix s. pleuralis	UNK	25/30	40/93	96/98	98	97/100	108/127	118/132	♀	♀		16 embryos 80/126		142/65
Natrix s. (*intergrade*)	21/26	27/33	43/70	72/77	76	76/81	106/126	115/131	♀	♀		UNK	UNK	
Coluber f. flaviventris	25/30	32/36	DOR. Damage too great for accurate count									5 eggs 103/164		
Agkistrodon c. mokasen	UNK	47/54	58/90	102/105	103	103/105	123/140	127/145	♀	♀		adrenal 135/139	143/147	154/45
Crotalus atrox	69/72	71/78	80/116	116/122	120	120/122	146/175	149/171	♀	♀		UNK	UNK	184/23
Crotalus v. viridis	63/67	73/80	80/112	117/122	122/123	123/125	151/177	156/179	♀	♀		132/138	145/154	187/19

The top number refers to the number of the ventral scale that is in line with the anterior end of the organ. The lower number refers to the number of the ventral scale that is in line with the posterior end of the organ.

Note the proportionately greater distance between the heart and the head in the pit vipers.

Note, also, the greater distance from liver to gall bladder in the copperhead.

2. Soak cotton with ether and drop it in the jar. Keep sealed for five to ten minutes.
3. When tilting the jar results in no response by the snake, the animal may be removed from the jar.
4. Break the spinal cord in several places. This will reduce reflex actions. This may be done with a dissecting needle in much the same way as pithing a frog.

B. External observations.

1. What is the color pattern of the snake?
2. Scale comparisons.
   a) Are the dorsal scales keeled or smooth? Compare with snakes at other tables.
   b) How do the scales on the head compare to the body scales? Compare those on your specimen with the preserved rattlesnake head on display.
   c) Observe the ventral scales in front of the vent and those behind the vent. Difference? Compare this feature with the preserved rattlesnake tail on display.
   d) Examine the anal plate. This is the scale that covers the vent. Compare this with snakes at other tables or snakes on exhibit.
3. Head.
   a) Observe the contours of the head and neck. How do they compare with those of pit vipers and corals?
   b) What is the shape of the pupil of the eye? Compare with poisonous snakes displayed. Are there any eyelids? Advantages?
   c) Are there any external ear openings?
4. Mouth parts.
   a) Try to locate empty spaces where teeth have come out. Do you note any apparent plan or pattern of loss and replacement?[1] A hand lens may be required.
   b) The tongue is housed in a sheath, but can usually be

[1] "In some reptiles the replacement of teeth follows an alternating pattern. Between any two functional teeth there is often an empty tooth space. As the new tooth erupts in to the space and begins to function the original teeth on either side of it are shed."—Bellairs, p. 17.

forced out by "milking" backward on the lower jaw. (Not too effective on preserved specimens.) Insert a pin through the nostril until the point appears in the roof of the mouth. Just ahead of this you will see two small pores, one on each side of the mid-line. These are the openings from Jacobson's organ.[2] It is believed by some investigators that snakes transfer particles from the outside directly to the pores of Jacobson's organ via the tips on the bifurcated tongue.

c) Manipulate the lower jaw to study its "moveability." Examine the glottis and fore end of the windpipe on the lower jaw. Notice how this moves. The perennial question asked by students about snakes is, "How can the snake swallow something larger than itself?" Storer in his *GENERAL ZOOLOGY* lists several adaptations for this feat:

(1) Junction of the two mandibles anteriorly by an elastic ligament.
(2) Loose attachment of the quadrate bone on either side to both the skull and mandible.
(3) Movement of bones of the palate.
(4) Backward-pointing teeth.
(5) Absence of a breastbone and attachment of ribs thereto.
(6) Presence of soft, elastic skin between scales on the back sides of the body, permitting wide distention.
(7) Thin and easily stretched walls of the esophagus and stomach.
(8) Placement of the glottis far forward, between the jaws and just behind the sheath for the slender tongue, which permits respiration during the swallowing of food.

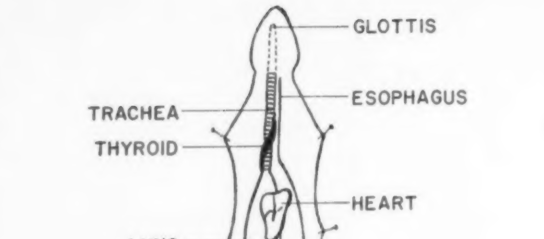
5. Determining the sex of your snake.
   a) Occasionally male and female may be distinguished by the difference in contour from just ahead of the vent to just back of the vent. Since the female has no hemipenes back of the vent, there is often an abrupt decrease in tail diameter at this point. A gradual tapering is likely to indicate a male.
   b) You may sometimes determine the sex by inserting a probe posteriorly through the vent. If it is a male, the probe may enter the invaginated hemipenis; the female body cavity ends abruptly at this point.[3]
   c) Perhaps you should check your snake for tiny tubercles on the chin or knobbed ridges near the vent.[4]

C. Internal observations.
   1. Exposing the internal parts.
   Place the snake (back down) on the 3 ft. board and fasten the head down with a nail through the tip of the nose. Do not put the nail too far back or you will destroy the brain. By squeezing in the sides of the body in the neck region, it is possible to push up the belly skin so that a small V-shaped opening can be made. *DO NOT CUT TOO DEEP!* Inserting the point of the scissors and keeping it turned up, slit the snake from the lower jaw to the vent. Careful not to push the scissors through the cloaca or posterior end of the intestine. Now stretch out the snake and fasten the tail to the board with a nail. Then pin back the sides so the internal organs are visible.

[2]"Each organ is a hollow domed structure situated beneath the nose and above the palate. The dorsal dome is lined by sensory epithelium very similar to that which covers the olfactory part of the nose."—Bellairs, p. 170.

[3]Schaefer, Walter, *Copeia*, 1934.

[4]"Many male snakes have tiny tubercles on the chin and knobbed ridges near the anus, these apparently helping in courtship and mating."—Pope, p. 147.



2. Locate the following parts without the use of probes. Parts are listed here as they occur from anterior to posterior:
   a) Windpipe (trachea), a cartilage-ringed structure.
   b) Esophagus, by the side of or dorsal to the windpipe, and approximately the same length.
   c) Thyroid, a pinkish gray ribbon of material on the windpipe just ahead of the heart. This gland is about one-seventh the distance between the tip of the nose and the vent.
   d) Heart, about one-fifth the distance between the tip of the nose and the vent. The heart will probably continue to beat during the entire operation.
   e) Liver, a long reddish organ of one lobe. The anterior end is a little over one-half the distance from nose to vent. The inferior vena cava may be seen lying along the ventral aspect of the liver. How does it differ from other vertebrate livers you have observed? Compare with a rattlesnake liver. Do you see the structural features that might be interpreted by some as evidence of evolution?
   f) Gall bladder, a dark grayish-blue (or greenish) oval-shaped organ one-half to one inch back of the liver (farther in the pit vipers). This is the source of the spoiled appearing color that so often shows in preserved specimens.
   g) Fat bodies, pale fatty ribbon-like structures often occurring in the snake all the way from a point near the gall bladder posteriorly almost to the vent.[5] This is used in the female snake during the period of yolk deposition in the egg.
3. Locating other organs by moving parts aside with the probes.
   a) The functional right lung which starts near the tip of the ventricle runs rearward for several inches. This can be inflated to show profusion of blood vessels at the anterior end and the almost complete absence of vessels in the posterior third of the lung.[6] In some snakes the vestigial left lung may be seen by careful examination at the posterior end of the windpipe.
   b) Stomach and intestines.
   A glass tube may be inserted into the pharynx to inflate the stomach. It is difficult to draw a fine line between the end of the esophagus and the beginning of the stomach. The walls

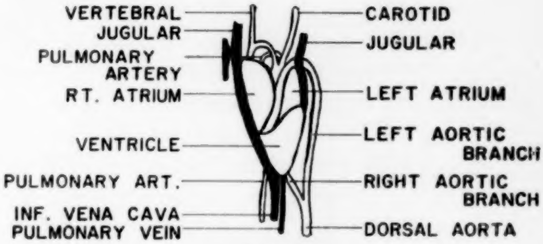
[5]In three pit vipers dissected during the preparation of this paper, fat bodies were found anterior to the heart. One of these was a diamond back rattlesnake, one a copperhead, and one a prairie rattler. The prairie rattler held a strip of fat three inches long anterior to the heart.

[6]"The right lung sometimes extends down to the cloaca, as in sea snakes, where it must have a hydrostatic function."—Bellairs, p. 165.

of the esophagus are very elastic as it must sometimes hold some food until the stomach has digested a part of the prey.[7] It is easier to determine where the stomach ends and the intestine begins. In some species there is an obvious constriction due to a sphincter muscle at the posterior end of the stomach.[8]

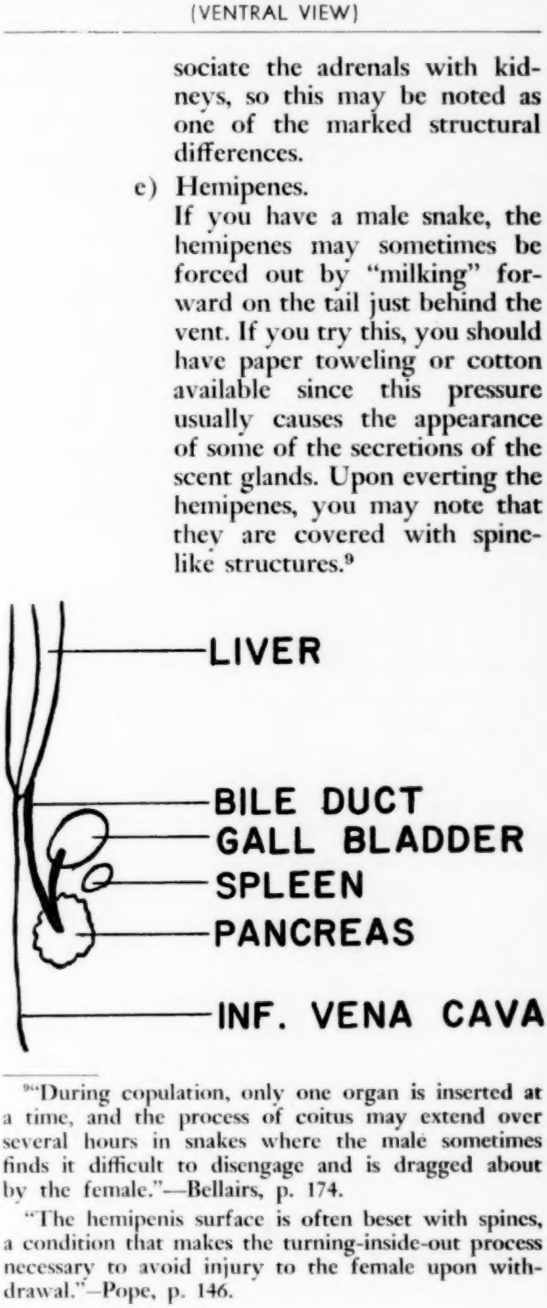
c) Spleen and pancreas.
The spleen and pancreas and gall bladder are seen in close conjunction with each other. The reddish colored spleen, conical in shape, is at the anterior end of the pancreas and may be considerably less than half as large as the pancreas which is usually a pale yellowish color.

d) Testes or ovaries and adrenals.
Testes are whitish colored organs found less than three-fourths the way back from head to vent. In a snake of 30 inches, nose to vent, the right testes will probably be ten and one-half inches ahead of the vent. Again, the right one will be ahead of the left. In the event you have a female, the pinkish ovaries are similarly located, and will possibly appear as a mass of beads on a string. Depending on the time of year, you may be able to locate the vas deferens or oviduct which carry the sperm or eggs to the cloaca. Eggs or egg yolks may fill much of the oviducts (Table I). Careful (very careful) examination may reveal the adrenals lying along the concave curvature of the gonads. They are a sort of light brown or tannish color, and in the 30-inch snake will be one-half to three-fourths inch long. You have probably come to associate the adrenals with kidneys, so this may be noted as one of the marked structural differences.



HEART
(VENTRAL VIEW)

e) Hemipenes.
If you have a male snake, the hemipenes may sometimes be forced out by "milking" forward on the tail just behind the vent. If you try this, you should have paper toweling or cotton available since this pressure usually causes the appearance of some of the secretions of the scent glands. Upon everting the hemipenes, you may note that they are covered with spine-like structures.[9]



[7]"The esophagus of snakes is highly distensible; it may have to accommodate a part of a large victim while the rest is being digested in the stomach."—Bellairs, p. 165.

[8]As in king snake dissected, July 15, 1958.

[9]"During copulation, only one organ is inserted at a time, and the process of coitus may extend over several hours in snakes where the male sometimes finds it difficult to disengage and is dragged about by the female."—Bellairs, p. 174.

"The hemipenis surface is often beset with spines, a condition that makes the turning-inside-out process necessary to avoid injury to the female upon withdrawal."—Pope, p. 146.

f) Kidneys.
Reddish bodies located about one-fourth the distance between the vent and the nose. They are said to be convoluted. This might best be described by saying that, when seen laterally, they look like the rattle from a rattlesnake tail. The anterior end of the right kidney is one to one and one-half inches ahead of the anterior end of the left kidney. Each kidney may be two to four inches long depending on over-all length of the snake.

g) Peritoneum.
You may see in your snake

Table II

NATRIX ERYTHROGASTER TRANSVERSA

	I	II	III	IV	V	VI	VII
	19 3/4"	24 1/2"	27 1/4"	33 1/2"	37 3/4"	42 1/2"	43"
ventrals	150	150	149	147	153	146	144
caudals	49	69	62	82	65	70	59
thyroid	23/24	22/23	?	22/23	23/24	21/22	?
heart	26/32	24/30	23/29	26/31	25/31	23/29	29/35
liver	38/71	39/70	38/70	44/70	40/72	39/73	39/72
gall bladder spleen pancreas	79/84	76/82	79/84	79/84	81/86	76/81	.77/82
right ovary	?	?/102	male	male	93/107	88/100	87/101
left ovary	?	103/107	male	male	102/116	102/111	102/113
right testis	female	female	93/108	95/103	female	female	female
left testis	female	female	105/119	103/111	female	female	female
right adrenal	99/102	96/99	102/105	99/102	99/102	95/97	?
left adrenal	109/112	108/111	112/115	108/111	109/112	?	?
right kidney	112/128	109/125	109/131	104/129	111/130	103/120	108/126
left kidney	120/124	117/133	119/139	114/135	119/137	114/129	116/132
fat	100/124	72/124	?	75/131	74/135	70/132	73/127

A single number refers to the ventral scale (scute) number. Where two numbers appear, the first is the most anterior end and the second is the most posterior end.

Numbers I, II, III, V, & VI collected in Saline County, Kansas.

Number IV collected in Neosho County, Kansas.

Number VII collected in Stafford County, Kansas.

The immediate purpose for comparing snakes of the same species but of several different sizes, was to observe whether age and size seem to have any effect on the location of the vital organs. The variations shown in the above table are slight enough that we are inclined to believe that they may be due to errors in observations or in counting.

some blackish membranous material which might cause you to think the snake injured, sick, or spoiled. This is the normal color of the peritoneum in some reptiles.[10]

4. Further observations which may be made by cutting or removing certain parts.
   a) Pyloric sphincter—
   Remove the posterior one inch of stomach and a quarter inch of the intestine in one piece. Insert one point of the scissors in the tube and cut lengthwise. Can you observe the nature of a sphincter? What food do you observe in the stomach, if any?
   b) Remove a section of the esophagus, insert scissors and cut it so the inner wall can be seen. Can you see the longitudinal folds that make possible its great expansion?
   c) To get to the brain, remove carefully the skin and then the bone from the top of the head. The various lobes should then be easy to see. Gently pick up the brain at the anterior end and on the ventral side will be seen hanging a small white organ, the pituitary.

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[10] The authors found this especially true in the live specimens dissected, namely, the four water snakes and the copperhead. Bellairs (*REPTILES*, p. 41) states that this is presumably due to melanin, but the significance is unknown.

Endocrinology Film

The Audio-Visual Center of Indiana University has released a new science film entiled, "Principles of Endocrine Activity." Using animation, the location and function of seven important endocrine glands, the pituitary, thyroid, parathyroids, pancreas, adrenals, ovaries and testes are shown for two animals, the frog and the chicken. Locations of the same glands are shown in the human male and female figures. The narration and demonstration are done by Dr. W. R. Breneman, Zoology Department, Indiana University.

Undergraduate Scholarships in Bacteriology

Indiana University will offer, beginning with the academic year 1960-61, Floyd Fund Scholarships for undergraduate majors in bacteriology. One scholarship will have a stipend of $1,000 for the year, another $500, and additional awards may be made. Entering freshmen will be eligible to apply. Transcripts of high school records, three letters of recommendation, results of National Merit Examination, College Entrance Board Examination, or similar material should be sent before the end of May to Professor L. S. McClung, Chairman, Department of Bacteriology, Indiana University, Bloomington, Indiana.

Serendipity*

HARVEY I. FISHER
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Dame Fortune has always *seemed* to play a major part in science. The words, "discover," "find," "reveal," and a host of others, are frequently used in newspaper reporting of science, and even in the scientific reports themselves.

Accepted definitions of these words, from Webster, enhance this illusion of random chance. "Discovery" and "revelation" are equated. The first definition of "reveal" is "To communicate or impart by supernatural means or agency; to make known or manifest through divine inspiration, a vision, or the like." And "find" is defined, first of all, as "To meet with, or light upon, accidentally;" Only far down in the fine print do we see "To come upon by seeking or by effort. To discover by study or experiment." We say that Curie *discovered* radium, that the law of gravitation was *revealed* to Newton, and that Fleming *found* penicillin.

Now all this, to my mind, has incorrect overtones, with hints of divine guidance, pots of gold at the ends of rainbows, etc.

Popular dramatization, in print, on the radio, and on television, has further given the public, students, and even teachers what I consider to be false impressions of scientists, the results of their observations, and how they obtained them.

I have chosen the word "serendipity" as the title because it is not in common use and has no special meaning for most persons. It can thus be used, without illusions or allusions, to illustrate the burden of my thoughts. It is possible that Walpole, when he coined the word in his tale of *The Three Princes of Serendip*, was not only indulging the public's fancy for fairy tales but was poking a bit of fun. "Serendipity" was defined as the gift of finding valuable or agreeable things not sought for.

As Pasteur has said, "Chance favors only the prepared mind." This means, of course, that the mind of the investigator must have been trained in the field of his endeavor and, very importantly, in other areas of knowledge that impinge on his work. Preparation of the mind implies that the scientist has long studied the problem, or related ones, and knows the implications, ramifications, and possibilities. The inquiring mind, the curiosity, is paramount. Objectivity, or the ability to treat events or phenomena without distortion from personal feelings or any other subjective bias, is another criterion of the prepared mind. Closely related to objectivity in thinking is the "open mind," one not closed to new ideas, thoughts, or reorganized views, one that will change as new facts or interpretations make change desirable or necessary. Also inherent is serenity or peace of mind, time in which facts, views, ideas, etc., may be reorganized.

Continuous work on a problem may not be as productive as alternate assiduous work and diversion, diversion being defined as working at something else. The German *Geistesblitzen* or flashes of inspiration or intuition were regarded as "lights flashing out from the psychological compression or reorganization of ideas," but they were also believed to occur only during periods of rest or relaxation following hard work or study of a problem. Poincaré ascribed inspiration or chance results to the working of the unconscious, *after* long periods of unfruitful labor and subsequent relaxation of the mind.

Modern scientists have been interpreted by themselves, not too facetiously, as belonging to one of three groups: 1) the "whittlers" or thinkers, the solitary ones with well-prepared minds who work individually and seemingly at a slow pace, with considerable time for contemplation; hence the name "whittler"; 2) the "team man" or one of a group of scientists, who knows his own field well but has joined other scientists with somewhat different backgrounds as a means of bringing a breadth of knowledge to bear upon an investigation; he frequently depends in large measure upon "bull sessions," or what the advertising man calls "brain storming" to give him inspiration and newly reorganized thoughts; and 3) the "business man-scientist" who gets funds, equipment, and other facili-

*Exerpts from the author's lectures to high-school students, sponsored by the American Institute of Biological Sciences.

ties for the first two groups. Although necessary to science, in our modern culture, this latter type can not be expected to maintain long his prepared mind or to have time for contemplation. He is too busy. We can not expect scientific discoveries directly from him. This means, then, that "results" must come from the first two groups, and curiously enough, the "results" from the two groups are generally pretty much different. Major advances in basic knowledge stem from the whittlers, to a very great extent. Teams and "projects" are adapted "to solving problems" and to "making use" of the ideas and facts emanating from the whittlers.

Keep these kinds of scientists in mind as we examine examples of serendipity to observe the kinds of so-called chance involved and the particular attributes of prepared minds.

It is said that King Hieron of Syracuse hired a craftsman to make a golden crown as a temple offering. The crown was made and delivered to the king who was pleased with it. Subsequent tests, however, showed that some silver might have been mixed with the gold. Naturally the king was angry; he ordered Archimedes to find a way to convict the goldsmith.

This was a problem, and it was a tough one. Archimedes knew that he would be a big success if he solved it, and a miserable failure in the eyes of the court if he failed. After long and apparently unproductive thought, he is said to have retired to his bath to think, as was the custom of the times. He was completely immersed in thought as he filled the tub with water. As he immersed himself (pun intended) in the tub, the water spilled over! This gave his mind the only clue that was necessary, and he is said to have dashed through the house, dripping and naked, shouting the now famous cry of "Eureka, Eureka." He had, of course, perceived the relationship between relative displacement and specific gravity. By measuring the water displaced by equal weights of gold and silver, he was able to offer proof that the crown displaced too much water to be pure gold.

Charles Nicole realized that serendipity played a part in his determination of the means by which typhus was transmitted, for he said, "This shock, this sudden illumination, this instantaneous self-certainty of a new fact, I have experienced it in my own life." For many years Nicole worked in the Moslem Hospital in Tunis. He observed typhus patients in beds right next to beds containing non-typhus patients. As had others before him, he noted that this close contact between typhus patients and non-typhus patients never resulted in new cases of the disease. However, out in the Arab quarter it was almost the rule that entire households came down with the disease, if one member of the family contracted it. He further noted that hospital attendants who worked only in the wards, although with typhus patients, never came down with the disease, but attendants who helped prepare the patients for reception into the hospital frequently contracted it. These are the facts, the only ones needed to solve the problem of transmission, but they had to be organized and contemplated.

Here is how Nicole described his revelation. "One day, just like any other, sunk no doubt in the puzzle of this contagion, in any case not thinking consciously (of this I am quite sure), I entered the doors of the hospital, when a body at the bottom of the passage arrested my attention. The light struck me; I had the problem solved. For the agent of transmission to be kept outside the hospital it had to be something outside the body of the patient—we took the patients in, but at the time of reception we shaved them, washed them, and took away all their clothes. The agent had to be on the body, not in it. This could only be fleas. Indeed, it was fleas, as subsequent tests showed."

This discovery seems like chance, but it really was hardly chance at all. Nicole had studied the problem, had thought about it for years, his mind was trained and was ripe for just the right observation to crystallize the solution. It was chance, yes, but chance that was almost a certainty. Someone, some day, was almost certain to have this flash when he stepped over a body in the doorway.

This psychological chance or the fortuitous combination of two different observations or ideas is a constant factor in almost all discoveries. Sometimes the combination of observations occurs, but the mind of the investigator is not prepared. An incident in the life of Luigi Galvani provides an example. Galvani noticed that the shank muscles of a

frog, when suspended on a wire, would contract if an electrical spark was produced near or on them. This was interesting to Galvani, and he performed the experiment under many different conditions, without ever seeing the real significance in this phenomenon. The importance of the observation escaped scientists until the time of Volta, whose detailed background in the physical sciences made it possible for him to see that an electrical current was being produced. Further thought and interpretation made it possible for Volta to produce the battery in 1800.

One classical example of the way a wrong observation of fortuitous chance hinders realization of the significance of something was Spallanzani's failure to recognize the function of the spermatozoon or male sex cell. In the light of our modern knowledge we feel that his experiments actually demonstrated the role of the male gamete in fertilization. We must be mindful of the fact, however, that today we have much more complete information and are less hindered by certain outmoded social and religious beliefs prevalent in the time of Spallanzani. His inability to determine the function of the sperm seems to have come about through his incorrect observation that he had freed a spermatozoon from its "animacule" and that the sex cell still maintained its activity.

There is, of course, another aspect of this failure to recognize the significance of an event; the researcher may recognize it but be unable to convince others of the truth. The following example gives solid support to the belief that scientists must have open minds, subject to change as necessary. The Hungarian physician, Semmelweiss, discovered the cause of puerpural fever, the childbed disease which formerly caused the deaths of so many new mothers. Noting that the death rate from puerpural fever was very high among laboratory assistants who did not wash their hands after autopsying victims of the fever, he instituted a policy of semi-antiseptic conditions for the assistants. There was a major drop in their mortality from the disease. Semmelweiss reported his findings to the Medical Council of Vienna, one of the most august medical bodies in the world at that time. Many of the leading obstetricians denied his findings so bitterly that Semmelweiss was forced to give up his position. He continued work and defense of his theories at the University of Budapest. Former colleagues in Vienna increased their attacks, and again Semmelweiss was compelled to resign. He died in an asylum. Twenty-five years later his views were supported completely by the studies of Pasteur and Lister. The world then accepted his theories, but how many women died unnecessarily in the quarter-century that the closed medical minds of Vienna had prevented his observations from being accorded just consideration?

For years the German chemist, Kekule, pondered the arrangement of carbon atoms in what we now know so well as the benzene ring. The idea of the arrangement is said to have come to him in a dream in which six monkeys were dancing in a circle. Without a "prepared mind" it is doubtful whether anyone would have noted an answer to a chemical problem in a dream about a troop of dancing monkeys. From a theoretical and practical viewpoint the dream was worth billions of dollars and untold, intangible cultural values, for much of our modern chemical industry is based upon the benzene ring and many items in our culture, items which we take for granted, could only be produced through knowledge of this structure.

Dr. Alexander Fleming in 1928 noted that one of the culture plates he was studying was contaminated by some microorganism from the outside. At that time he was working with a group of organisms known as staphylococci, several of which are important causative agents of infections in human beings. Such contamination was frequent, an accident that happened to all workers from time to time.

Now most workers would have discarded the culture, told all concerned that more care had to be taken, and then proceeded with the main item of interest. But Fleming had a great amount of curiosity, and he studied the culture in great detail. He noted that his little organisms, the staphylococci, were killed in a circular area around the growth of the contaminating organisms. Thus was born the concept of antibiotic effects. The observations, however, were really more than 50 years old, for Tyndall, Pasteur, and Joubert had made nearly identical observations. In contrast with the earlier workers, Fleming did not cease his work on the effect; the results of his continued labors are well known. The point is, how

frequently does opportunity knock, how often are all the necessary events or observations laid out for the prepared mind to recognize and to organize, and how often are they missed?

The elements of chance in Fleming's studies were these: that the culture would be contaminated, that the contamination would be observed, that the contaminant would produce a material affecting the staphylococci, that the staphylococci would be sensitive to the contaminant, and just as importantly that Fleming would follow up his initial observations.

The fact that this antibiotic effect had to be observed at least three times, and presumably recorded in print three times, brings up another element of chance in science—the dissemination of the results of scientific observation. Who reads what when is most significant! Most of you are perhaps aware of the 40-year delay in the full consideration of Mendel's work and the consequent delay in the development of the field of genetics. Perhaps you are not aware that the mosquito was indicated as the agent transmitting malaria nearly 100 years before the idea was established as a fact. During that century malaria continued its death-dealing in many parts of the world. The simple observation by an Abbe, published in "A Voyage in Dalmatia" was this: "All inhabitants of this area sleep in open porches where they can be on guard against their neighbors. A clergyman, a priest, a man of lively spirit, told me he suspected that the fevers plaguing the inhabitants of this country were due to the bite of these insects. It is not impossible that the fever is communicated in this way; at least the conjecture is very ingenious."

We do not know whether this statement resulted from clear understanding or speculation, but this is unimportant. In either event, if the printed word had come to the attention of the prepared mind of a scientist, rather than persons untrained and busy with their own affairs, the idea would have been tested.

At the risk of continuing too long, I should like to mention briefly one more element of chance in science, the chance that the researcher, for reasons best known to himself, does not publish his observations, or only does so long after they were made. Why, for example, did Newton delay so long in making known his fundamental observations of the heavens, of mathematics, of optics? I suspect the problem with at least some modern researchers is that they are not quite confident of the results and do not want to face possible criticism. To me this is not a valid reason. When one has taken all possible means to assure the accuracy and significance of his work he should publish. Science is not built upon the accuracy or fallibility of any one person. No scientific discovery is accepted or rejected without testing, and no major idea has long remained unchanged, at least in part. Science, although its goal is everlasting truth, or beauty as one of my colleagues would say, is characterized, and quite rightly so, by everlasting change and the discarding of previous views.

International Symposium

An International Symposium on Growth; Molecule, Cell, and Organism, will be held at Purdue University, Lafayette, Indiana, June 16, 17, and 18, 1960. For information, write: Dr. M. X. Zarrow, Department of Biological Sciences, Life Science Building, Purdue University, Lafayette, Indiana.

Inspirationally Speaking

Max Freedman, Washington correspondent of the Manchester Guardian, in an address to the 11th Annual Conference of the Commission on Teacher Education and Professional Standards, made the following statements: "Teachers who are remembered with gratitude by their students are the ones who have walked with ease on the heights. Seldom are the teachers remembered who find the short-cuts; the easy road to learning."

He states, "Education is useless if you try to make it easy. If the teachers set the standards high the class will respond whether the subject is history, science, or whatever.

"If I were a teacher today, I would try to get my classes to challenge the axioms. I would try to get them to see whether these axioms by which men live should be honored or whether we need new incentives and goals."

Mr. Freedman concluded, "The classroom is a better world within the world. The classroom has a fairness that shames the rough standards of the world."

The Effective Biology Library

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Biology teachers and pack-rats have several traits in common, but one is especially noteworthy—both are inveterate collectors. It will be the purpose of this article to point out how one type of collection—biological literature—can be better utilized. Few biology teachers will take issue with the statement that this literature is indispensable to teaching. However, it is suspected that most are victims of a hodge-podge collection of material in which that critical experiment or reference eludes them when they most need to find it. How can this shapeless mess be turned into a systematic biology teaching library which will assist in doing a better job of teaching? It takes a small amount of initial work, but it will help economize time after it has been set up.

Periodicals are felt to be the most valuable part of a teacher's library, for here is literature which reflects current research, and which is difficult, if not impossible, to replace. Therefore, one of the first steps to be taken in setting up a systematic teaching library is some method of keeping these from getting damaged and lost. The easiest and least expensive method is to place them in some sort of container. This may be a stationery box, a photographic sheet film box (especially suitable for *American Biology Teacher*, because it just fits); or a cake mix box. Large, heavy manila envelopes will make very serviceable holders. Pamphlet boxes designed for the purpose, self-made, with strips of wood forming the top, bottom, and front, with heavy fibreboard* forming the sides may be used. Pamphlet boxes may be purchased from a library supply house, made up from a number of materials. All of these containers will keep periodicals neatly together, and protect them from dust and light. One disadvantage of either the phamphlet box or the manila envelope is the fact that individual magazines can be removed from the volume and are then easily lost. This can be prevented by drilling three or four holes in the left margin of a volume of magazines and tying them together with heavy string. Greater protection will be afforded by adding a front and back cover of heavy paper or cardboard.

Reprints and pamphlets present somewhat more of a problem because of their variation in sizes. These too may be filed in pamphlet boxes or manila envelopes. Perhaps a more satisfactory procedure is to place them in folders in a filing cabinet.

Books are much easier to care for because of their more durable binding. If these are loaned, it is a good idea to insert a pocket in the back, similar to those used in lending libraries, to hold a checkout card. The school librarian will probably be willing to install these if it is mentioned that the books are used as a supplement to the library. When a book is loaned, the borrower's name can be placed on the card as a reminder of the book's whereabouts. This tends to keep reference libraries intact.

Literature can be filed in a number of ways. It may be filed alphabetically by subject; i.e., Phylum *Protozoa*, respiration, embryology; or miscellaneous; or it may be filed alphabetically by author. This latter system requires a cross index. The difficulty with either of these methods is that new materials have to be inserted into the existing collection; thus requiring periodic revision to accommodate new

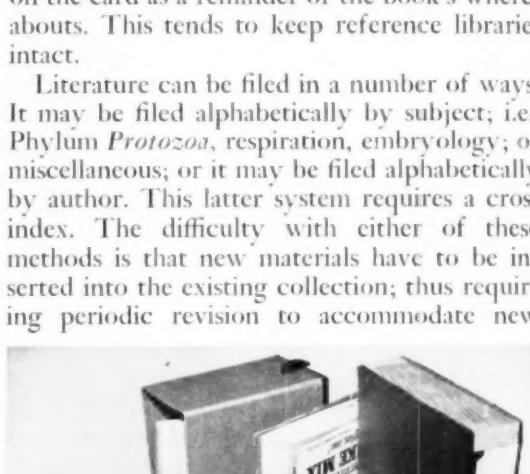

Figure 1. Types of boxes which make satisfactory, inexpensive holders for periodicals, pamphlets, and reprints.

*A heavy, non-corrugated fibre board, called "Easy Curve" is quite durable, and inexpensive. It may be obtained from most lumberyards.

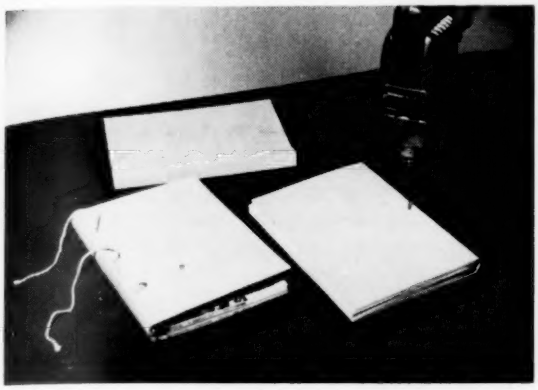

Figure 2. An easy method of binding periodicals to prevent loss. (Photographs by Wm. D. Jackson).

entries (1). This is avoided by using yet another system, that of placing them in the file in the order in which they are procured. As new material is acquired, it can be assigned an accession number and added at one end of the collection. This is also convenient because the materials are easily replaced after use by merely placing them in the correct numbered sequence. This system is especially well adapted to reprints and pamphlets. It requires a card index. Lyman (6) and Dice (2) give a more complete evaluation of these systems. Gier (3) and Carlander (1) give suggestions for systems specifically related to reprints.

Eventually, the need for an index system is sure to be felt. For this reason, it is recommended that the index be started as soon as possible after the literature on hand has received proper care. According to Lyman (5), two of the main considerations in developing a system are [1] keep it simple, from a mechanical point of view, and [2] keep it uniform.

If the system becomes too elaborate, the task of keeping up with the clerical details becomes formidable. A system which has proven to be quite convenient is to file the literature alphabetically by author or title, in the case of periodicals, and the card index by subject. Using this method, if your teaching approach changes, the card index only has to be rearranged. It is much easier to shift cards than books.

Concerning uniformity in the systematic library, the card shown in Figure 3 has proven to be quite satisfactory. This 3 x 5 index card was printed in the school's vocational print shop. It could also have been mimeographed.

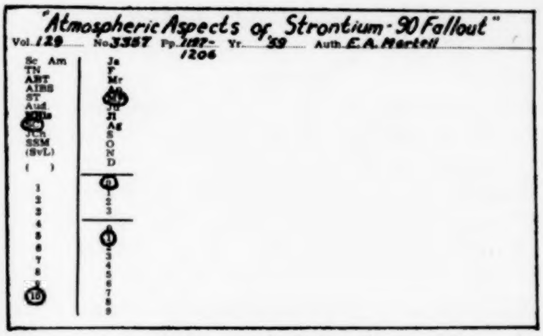

Figure 3. An index card designed to reduce the amount of writing required to a minimum.

On it are abbreviated the names of the periodicals which are regularly received. The blank in the parentheses can be used for single copy materials or to indicate that the reference in the library is a reprint. The numbers in the first column can be assigned as code numbers to new subscriptions which were not abbreviated. Perhaps the last number in this group could be circled to indicate the presence of a bibliography in a reference. Months of the year are abbreviated with a number code for the date. The card shown is made out for an article by E. A. Martell, "Atmospheric Aspects of Strontium-90 Fallout," in *Science*, Volume 129, Number 3357, on pages 1197 to 1206 in the May 1, 1959 issue. In practice, either a brief abstract of the article is included; or if the magazine is not to be retained, and the article is short, it is clipped out and fastened directly to the card. The effort here in designing the card has been to reduce the amount of writing required to a minimum.

To assure that a maximum of usefulness will be derived from all the literature available in the biology teacher's library, it is suggested that individual experiments from books, laboratory manuals, and other sources, as well as those from periodicals, be included in the index. The reason for this becomes apparent when it is considered that all of the references which relate to a particular phase of biology will be grouped together. This will suggest a large variety of class exercises which might otherwise have been overlooked.

The most difficult task in keeping a systematic library is getting it started. Contrary, however, to Hedgepeth's (4) rather humorous remark that "scientists can be divided into two classes, those who file reprints, and those who work," it is felt that such a personal library will greatly aid the biology teacher.

Is not a systematic teaching library merely a scientific approach to a teaching problem?

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BIOLOGY IN THE NEWS

BROTHER H. CHARLES, F.S.C.
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HOW TO LIVE WITH YOURSELF, Dr. Murray Banks, *McCall's*, March, 1960, pp. 116-117, 142-144.

How do you react to the ordinary problems of life? What are your motives for doing things? This article stimulates self-examination and suggests ways by which we may learn to make the most of our inner workings.

WHAT SHOULD YOU TEACH YOUR CHILD ABOUT DRINKING? Selden D. Bacon, *McCall's*, March, 1960, p. 183.

Do parents' remarks about drinking have any effect on the conduct of their children? This short article can stimulate some effective discussion about alcoholism.

DON'T FALL FOR FOOD FADS, *Good Housekeeping*, April, 1960, pp. 59, 109.

Short, to the point advice about food fads and the activities of food quacks, both amateur and professional. It is aimed to prevent spending good money on worthless products.

THE RACE FOR HEALTH, Eugene D. Fleming, *Cosmopolitan*, April, 1960, pp. 52-57.

A comparison of the advances made in medicine in the United States and in the Soviet Union. Short descriptions of some of the latest medical advances now available to us are included also.

AMERICAN PIONEER MAN OF SCIENCE, *Life*, February 29, 1960, pp. 50-64.

Pictures of inventions and excerpts from the reports of scientific experiments made by Benjamin Franklin. His passion for facts acquired by original investigation serves as a great inspiration to others.

PATHWAY INTO THE MIND, Robert Coughlan, *Life*, March 7, 1960, pp. 106-122.

An account of some of the effects of hypnosis when used by competent physicians and dentists. The use of hypnosis in the treatment of mental ills receives special attention.

ALL ABOUT DIETS, Ruth and Edward Brecher, *Redbook*, March, 1960, pp. 38-39, 79-84.

Ever hear of the hypothalamus? You may be hearing more about it and its action on the appetite. With more than 30 million Americans overweight, the action of this structure may be an important factor in controlling man's desire for food.

THE FARMER'S SIDE OF THE CASE, Mary Conger, *Saturday Evening Post*, April 9, 1960, pp. 36-37, 100.

The farm problem is critical. Who will be our future farmers? This article gives the picture as it appears to a farmer's wife. Good discussion material.

THEY VOLUNTEER TO SUFFER, Howard Simons, *Saturday Evening Post*, March 26, 1960, pp. 33, 87-88.

Normal healthy Americans who willingly starve, freeze, and even get sick become wonderful assets in the laboratories of the National Institutes of Health. They not only act as controls in the tests of drugs and procedures for the treatment of disease, but they also give the doctors accurate data as to what is really normal in a person.

On the Isolating Mechanisms of Drosophila

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> Of animals, some resemble one another in all their parts, while others have parts wherein they differ. Sometimes the parts are identical in form or species . . . as in the case in such animals as are of one and the same genus.
> —Aristotle.

It is an *a priori* conclusion that every individual, regardless of classification, is unique in himself, differing in a multitude of ways from every other individual that lives or has lived. Such organic diversity has been the subject of speculation and investigation since the days of the ancients. In recent times it has been studied by the refined techniques of the scientific method.

While much attention is given in all branches of the biological sciences to observable similarities and variations, a new fact emerges, almost as astonishing as the original one of organic diversity: the diversities and variations among living individuals are discontinuous themselves.

It is apparent that were all of life one continuous variation, then a single entity would be connected in a series with every other living entity. However, the plant and animal kingdoms do not exhibit such continuity. Instead of one continuous series extending from the simplest protozoan to the highest living organism each member of which is connected to every other by intergradations, we find groups of organisms with common properties. These groups are separated from other groups of organisms with common properties, with intermediates very often lacking.

When each group or "cluster of individuals," to use Dobzhansky's phrase, is examined one finds it also has properties which delineate it from every other group (1). Thus, in place of a continuous series we see a hierarchical order, a crucial distinction for a methodological classification of living things. This hierarchy extends to the smallest category, namely the species, with which I shall be engaged within the limits of this paper.

One must remember that it is the distinctness of the species' own particular gene complex which dynamically separates it from every other species. But if the sexual process, which is the predominating mode of reproduction within the animal kingdom, were an unconfined mechanism, then a breakdown of these gene complexes would occur. This would result in the dismembering of the hierarchical order with the appearance of an almost infinite array of Mendelian recombinations.

It is certain, therefore, that life as we know it is made possible only if unlimited hybridization is prevented from causing such genetic disintegration. Here we have a real paradox: the progress of life is possible only with the advent of new gene patterns. But if these are not permanent, dissolution of species may occur. This antinomy seems to be resolved by a modern view:

> ". . . the process of evolution may then be described in a most general way as a result of the interplay of forces tending toward fixation of the already tested gene patterns, and forces producing new gene patterns, some of which may become the forerunners of the world to come." (2)

Lamarck and Darwin were among the first to point out that interbreeding hereditarily distinct individuals can easily result in the dissolution and submerging of their differences (3, 4). This rarely happens, however, since specific agencies keep the species in question both separate and distinct. The agencies by which these groups of individuals are kept from interbreeding are strikingly dissimilar, even between species which are morphologically rather closely related. Gene exchange between pairs of species is thus prevented usually not by a single, but by several isolating mechanisms. Each mechanism of itself is usually inadequate to maintain the species separation, but when combined they do so quite effectively. These agencies afford one a most profound insight into law and harmony at the basis of the natural order.

In a series of valuable articles appearing during the last quarter-century, Theodosius Dobzhansky has addressed his attention to the

isolating mechanisms of *Drosophila* and their possible genetic explanations. He is one of the clearest and ablest writers in biology today. In Chapter Seven of his beautifully written work, *Genetics and the Origin of Species*, he has amplified his views on the four major mechanisms by which species are successfully isolated from each other: *geographical*, *ecological*, *sexual*, and *mechanical*. I shall discuss the first two and what happens when they break down.

Geographical Isolation

It has been found that if females of the same species, but of different geographic origin, are confined with males of one of these strains under laboratory conditions the mating choice depends on the particular strain and the distances between the localities from which they were collected. Either preferential or random unions are the result. One may find examples of such unions in the differing mating preferences shown by races of *Drosophila pseudoobscura*, *D. miranda*, and *D. willistoni*. These organisms dwell on the west coast of the Americas from British Columbia to Southern California, occupying areas from the shore inland to the eastern slopes of the Sierra Nevada-Cascades range.

The areas inhabited by the three species are not completely isolated geographically. They occur together in so wide and broad a zone that were their interbreeding not prevented by means other than geographical a large hybrid population would result. As far as can be ascertained, however, no hybrids between the three species are found in any of the overlapping areas.

These organisms illustrate so well the interdependence of both geographic and sexual isolation: were sexual factors not extant here, diffuse hybridization would dissolve the species, and geographical isolation would then have no meaning. By contrast, individuals accustomed to living in one area are effectively prevented from interbreeding with individuals of a distant habitat, regardless of any sexual isolation (5, 6, 7). This is what is meant by "geographical isolation."

Ecological Isolation

When ecological isolation characterizes two species they occupy two entirely different habitats, called "ecological niches," though they remain in the same general area. It often happens that closely related species, and often ones with very similar morphological characteristics, may inhabit the same geographic territory and yet permanently retain their species identity. Examples would include *Drosophila pseudoobscura* and *D. persimilis* living in the same area. Such ecological factors may entirely prevent interbreeding from occurring. If interbreeding does take place these factors may then control its frequency so that the zone of hybridization does not then diffuse unrestrictedly (8, 9, 10).

Both *Drosophila pseudoobscura* and *D. miranda* reside in forests. They are not ordinarily found in treeless or desert localities. In southern California *D. pseudoobscura* lives mostly in islands of trees growing on rather high mountain ranges. The combined distribution of *race A* and *race B* of *D. pseudoobscura* is similar to that of the western yellow pine, *Pinus ponderosa*, although it occupies a somewhat wider range. These flies are not found only in that area, since vigorous populations of either race can be located in other coniferous trees such as in *Pseudotauga*, or even in deciduous forests (11).

However, these mechanisms for the isolation of one species from another are not always infallible. There remains the possibility that two different species may interbreed, which they often do, producing forms that will diverge from the original genetic organization. Such a process is called "hybridization;" it is meant to denote those unions of individuals of different families, genera, or species. When hybridization does take place then nature has available what Ernst Mayr calls "one last trump card," designed to prevent the appearance of sexually mature forms (12). This is accomplished by producing either inviable or sterile hybrids, as I shall now discuss.

(1) Lowering the viability of the hybrid zygote may prevent sexual maturity. The F_1 offspring from *race A* of *Drosophila pseudoobscura* $\times$ *race B of D. persimilis* seem about as vigorous as the non-hybrid individuals of either race, although some of the progeny thereof frequently show certain aberrations in structure and function. The male offspring from the cross *D. pseudoobscura* ♀ $\times$ *D. miranda* ♂ are almost completely inviable. Of the fertile individuals, reciprocal crossing pro-

duces males that are abnormal in appearance, sluggish, and rather short-lived.

The life-span of such a hybrid may be cut short at most any stage of its development, from the first cleavage of the egg to the late embryonic or post-embryonic development. One may observe cytogenic aberrations, chromosomal incompatibilities, and abnormalities in growth and organ-forming processes. Other than these irregularities there seem to be no clear explanations of the physiological disturbances that prevent the hybrid from reaching maturity.

(2) Sterility of the F_1 hybrid offspring in varying degrees may effectively prevent further genetic dispersal. Interspecific crosses frequently produce offspring which are equal or superior to their parents in vigor, but they are, nevertheless, partially or completely sterile.

Sterility is usually caused by a failure of chromosome pairing at meiosis. This must have a cytological basis, such that possible translocations and inversions of chromosomal material of one species will find no homologue in the chromosomes contributed by the gamete of the other species. Therefore, chromosome pairing might be incomplete or absent, the first meiotic division might be abortive, the second absent, and, instead of normal gametogenesis, degenerative polyploid cells would then be produced. Another possible agent working in conjunction with chromosomal disturbances might be the incompatibility of the cellular actions of genetic factors contributed by each parent (13, 14).

Dobzhansky contends, however, that there is no known example of sterility on record either in plants or animals which has been conclusively proved to be entirely chromosomal in nature. The main argument that chromosomal sterility exists at all, he maintains, is the occurrence of fertile allopolyploids derived from sterile, disploid hybrids, but these are not decisive. The precise mechanism through which sterility is effected is most likely through the interactions of certain gene arrangements contributed by the two ordinarily incompatible parents; the genes exert their deleterious effects through some intracellular activity.

It probably remains true that no single factor causes the isolation of a given species. Rather, isolation is established by a complex interaction of factors ranging from geographic, ecological, sexual, mechanical, and also through factors affecting sterility and inviability (15, 16, 17, 18).

We may make several observations in reviewing the above isolating mechanisms in *Drosophila*.

(1) Sexual isolation between two species is not likely as complete under laboratory conditions as it is in nature. This is inevitable, since no laboratory procedure, however refined and well-implemented, can ever provide an exact duplicate of the complex conditions found in the field. Strains that are studied in the laboratory may exhibit activities and functions that would never be followed in their natural habitat. One can never duplicate the ecological niche a particular species may occupy. This illustrates how critical may be such factors as climate, altitude, ecological conditions, and population density, in addition to the courtship patterns all providing complete isolation of one species from another.

(2) Mating between flies is not really accomplished entirely at random, as I suggested earlier. It is rather the net result of a highly developed constellation of discriminatory activities which are conditioned by the above factors. Conspecific matings are much more frequent than heterogamic matings. Laboratory conditions cannot bring out all the specific reasons for this.

(3) One may observe a variety of agencies in operation between races A and B of *Drosophila pseudoobscura*. There may be (a) a definite, though incomplete, geographical isolation; (b) a weak ecological isolation; (c) a marked sexual isolation; (d) a complete sterility of the F_1 hybrid males, and; (e) a low viability of the offspring of the backcross F_1 hybrid females to males of the parental races. None of these mechanisms is sufficient to accomplish isolation by itself, but together they serve the purpose quite effectively. Interbreeding of *D. miranda* with either race of *D. pseudoobscura* is precluded by (a) a strong sexual isolation, (b) a decrease of the viability and (c) a complete sterility of the F_1 hybrids of both sexes (19, 20).

While dealing with the problem of isolation in races of *Drosophila virilis* in the middle-western region of the United States, Stalker writes of a "hybrid challenge" which reflexly calls forth isolation between the races involved. He agrees largely with Dobzhansky's point-of-view and quotes:

> ". . . the occurrence of hybrids between races and species constitutes a challenge to which they respond by developing or strengthening isolating mechanisms that would make hybridization impossible." (21).

The genes producing these isolating mechanisms, having a positive selective value at the border zone of contact between the two races and a neutral value within each race, would thus differ along the entire border zone.

He asserts further the possibility that "chance fixation" of certain genotypes could produce isolation. The genetic isolating mechanisms might then be acquired, not by the challenge of hybridization at the point of contact, but independently during evolutionary changes which result in increasing the differences between subgroups. Interspecific sterility may then occur as a by-product of evolutionary divergence.

According to this interpretation two or more once co-existent and similar populations, if they accumulate more and more genetic differences during the course of isolation, will, in time, produce reproductive stability. In other words, any gene difference may produce a partial isolation; any mutation that may arise during geographic isolation will likely have a similar isolating effect. In time two populations would then become different in many genes, and there would be by chance enough isolating ones to prevent future interbreeding. However, in many strains of Drosophila there may be differences involving dozens of genes (22, 23).

Muller claims that isolation may arise through the change of gene functions during the phylogenesis of a race (24, 25, 26). The functions of certain genes gradually undergo changes fitting them for taking over other processes, some of which would eventually participate in isolating procedures. However, isolating mechanisms usually appear to be *on-the-spot* devices designed to prevent future gene flow between embryo species rather than incongruities originating in accidental changes in gene functions. Muller's view thus seems to be no better than the generalized suggestions of hybrid challenge and chance fixation outlined above.

Another tentative hypothesis based on the work of Fisher has been suggested by Dobzhansky. Physiological isolating mechanisms are a product of natural selection. This view arises from the premise that the genotype of a particular species must be an integrated system adapted to the particular niche in which it lives (27, 28). The difficulty with Fisher's work, which resembles Stalker's contribution, he points out, lies in its corollary: namely, that isolating mechanisms arise many times in response to the challenge of hybridization and lead to the formation of poorly adapted genotypes. This view could not explain how isolation would arise on islands or in mountainous areas where there is no possibility of hybridization, again reminding us that the hybrid challenge explanation is inadequate.

Dobzhansky bases his physiological isolation through spreading and establishing mutual genetic conditions which are eventually strengthened and fulfilled by natural selection. This improvement on Stalker's "hybrid challenge" and Muller's "changes in gene functions" appears to be substantiated in the great intensity of isolation *Drosophila pseudoobscura* exhibits in the areas where *D. miranda* also resides. Perhaps this hypothesis would be verified were further data available on isolating genes in areas where there is no danger of hybridization (29, 30, 31).

We see that the real nature of isolating mechanisms lies in the nature and functions of the genes themselves. The reproductive biology of the new species must insure procreating offspring sufficient not only for maintaining it on a survival level but also concurrently preventing multiplication of hybrids with other species. That this occurs in nature can be amply demonstrated. How it arose is not at all easy to picture or establish.

The contemporary view is that geographic races become species if isolating mechanisms arise which are capable of achieving permanent separation. This does not mean that forms of the same species which are geographically isolated always become distinct species. Rather, a group of individuals which has acquired the species level must first have passed through a period of isolation from the original parent stock while the factors producing reproductive isolation became permanent in that group.

Geographic isolation of two originally identical groups may thus lead to evolutionary divergence. If they overlap and once again occupy the same territory, either no interbreeding will take place, or the hybrids that

form will be sterile or inviable. The modern view of the origin of species, different in many respects from that of Darwin, is that speciation is always preceded by geographic isolation. During such time the development of physiological isolating mechanisms appear and achieve permanence in the new species. If intermixing with members of the original parent population takes place again through further divergence in space no breakdown occurs in gene characteristics.

We may then agree that the possibility of our acquiring a deeper understanding of evolutionary processes operating at the species level rests on solving the problem of the origin and nature of the isolating mechanisms. Indeed, the complex mechanisms isolating species from each other suggest the only true characteristics of a given species.

> "The genetic nature of species differences is therefore a study of the hereditary nature of the isolating mechanisms, and of their rôle in the dynamics of Mendelian populations." (32)

The real causal factors in the origin of isolating mechanisms remain shrouded in mystery. To say that isolation has a genetic basis does not answer our problem. It merely localizes it and, indeed, increases the mystery. When we ask ourselves what are the nature of these "factors" which condition gene change, we are at once face-to-face with the most enigmatic and intriguing question of all: the nature and meaning of life itself.

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Royalty, Rebellion, and Retirement, Three Rs of Nature Writing*

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If the title of a talk or article should be definitive, the title of this one is a failure. Every word in the title may have more than one interpretation. Royalty may refer to reputed quality or to a mercenary reward. The virtue of rebellion depends on what is being rebelled against. Retirement I am sure can be a joke, and some day I hope to try it as a recreation. Usually two of the standard three Rs are not Rs at all, and if there is cosmopolitan human activity, it may well be nature writing. Under these circumstances I have almost complete license to do anything I please, and since this is what I should probably do anyway no one will be surprised at the result. I shall not even follow in the text the order suggested in the title so the result may be complete confusion out of which each of you may establish your own chosen order.

In my judgment good nature writing must be a sort of disciplined fun. Much that passes as nature writing in periodicals in elementary and secondary texts, and even in books, is disciplined to the minimum by the facts of life. This applies to the works of some who have made the greatest names for themselves, and sometimes this is wholly inexcusable. When I joined the staff of Nature Magazine in 1925 I was asked by the editor to pass judgment on an article for which the editor had paid a number of hundred dollars to an author whose surname initial is the same as mine, and it was not Pack or Pearson or Peterson but sounded something like that. The author pictured a dour Calvin Coolidge smiling one Christmas morning at some snow-covered pines outside the White House where a brilliant red cardinal was sporting in the snow with an equally spectacular red and black male scarlet tanager that got left behind when his parents took the southern migration. There was so little possible valid natural history in the story that I told my boss that if he published it he could accept my resignation. It was never published by the magazine which subsequently carried an article of mine in every number for over thirty years. That article by a celebrated nature writer can hardly be considered as real nature writing. I rebelled against it, and the royalties I receive from more disciplined but possibly less thrilling writings help me considerably in my retirement.

*Presented to the American Nature Study Society in their meetings with the AAAS in Chicago, December, 1959.

That experience gave me great faith in the value of trying to stick to the truth even though it requires considerable effort to learn what the truth might be. I have made my share of mistakes but have done all I could to avoid them, and when they were called to my attention I have done all I could to acknowledge and to correct them. At one time I wrote an editorial page based upon mistakes I had made, but it was one of few articles I have written that was rejected by the publisher. My chief resentment against the writers of the most successful elementary science texts is their stubborn attempt to defend as truth things they must know are not true.

Nature writing is such a varied feast that it might be well to consider the types which have gained considerable recognition and may offer considerable reward to those considering entering the nature writing field. Rewards may of course be financial, professional, political, or in the realm of self satisfaction. I have explored each of these possibilities and have some convictions which I believe I might defend with statistics. Some that offer the greatest financial reward have the least professional value, and some of great professional value have little monetary worth. I estimate that in 1959 I wrote about 100 printed pages of new material that was published and about twice that number of pages that will be published. Of about 35 million pages of my material published in 1959 about 4,500,000 pages had been published previously and earned more than half of the money earned by me. This came from about 3,000 individuals of the slightly over 3 million individuals who in the year periodically or otherwise received my material in this year. If I was able to influence any considerable proportion of these 3 million individuals, I must accept this as a rewarding experience because monetarily the returns from all of my writings during this year were less than those earned by an electrician's assistant who did some work for me last week and told me of his year's earnings. In spite of this that financial return for writing done on the side was greater last year than the retirement allowance I received at the end of over forty years of university teaching. Those of you then who are where you can see the time when you will be let out to pasture may well give some consideration as to how you may supplement your income when that time comes, possibly through the nature writing avenue. This report given so far may give the impression that I have a phenomenal income from nature writing where as a matter of fact the writing has merely made it possible for me to have about the same income I had before I retired from the teaching field. With the advent of social security next summer at age 72, I shall be able to maintain that income and do a little real retirement. Maybe then I will get caught up on my fishing. Rather I suspect that I shall be buried in a manuscript about fish on which I have been working for some years.

Financial earnings from nature writing should be considered from more than one angle. For forty years there has hardly been a two-month period in which an article of mine has not appeared in print. For only ten of those forty years has this return come from royalties that can be considered as a sustained nature. I am confident that had I concentrated on this kind of work I should now be better off than I am financially, but the returns from the magazines made it possible to improve the quality and quantity of the royalty earning projects. For years I ploughed back every cent I earned from magazines into building up a "morgue" of illustrations of value in producing more substantial works. I now have about 4,000 drawings that I can use to illustrate my writings for the rest of my productive life. I could not have financed the production of this aspect of nature writing without the support of the more ephemeral magazine writing.

It may be interesting to examine the "AAAS Science Book List" published in 1959 which presents the judgment of the Association as to the most indispensable books for a science library. They set aside about 100 books in science and mathematics as being indispensible, and two of these are by former presidents of the American Nature Study Society. I find no other of the science teaching societies with this distinction. One of these books was first published in 1911 and still maintains itself in this list. It is Mrs. Comstock's *Handbook of Nature Study*. I find none of the magic names of the leaders in science education as such in this list. Maybe there is a reason.

There is no one channel of nature writing that can be considered to monopolize the field.

I am satisfied that the production of good solid basic material is the most rewarding in the long run if you have to live with yourself as well as with a small bank account.

I have never seriously tried the production of precollege text material but am satisfied that it offers tremendous possibilities in many ways. I doubt if the quality of these texts is increasing as it should. Rachel Carson through *The Sea Around Us* has demonstrated effectively the reward possible in straightforward high quality exposition in prose. Her combination of sound scientific fact with exquisite literary skill presents us all with a goal to serve as a guide. Certainly former presidents of this Society, such as Edwin Teale, Roger Peterson, Richard Westwood, and W. G. Vinal have made their important contributions to the nature writing field and been rewarded for their efforts.

I rather believe that the most successful nature writing will continue to concern itself with the commonplace. Rachel Carson's tides are going to persist for quite awhile yet, and Mrs. Comstock's moths and butterflies are going to interest generations of youngsters long after the current crop of textbook writers have been forgotten. Somebody someday can write a textbook that can stand the erosion of years of critical examination.

There will always be a frivolous group that want their information jazzed up and made easy to understand. For the last two years I have toyed with the cartoon technique and have had a page in Boy's Life which has been fun to write and which I think may well improve my ability to write in other fields. So far as numbers reached is concerned this has been my most rewarding recent field of endeavor. I certainly do not think it is necessarily the best method to be followed, but it does provide a challenge that some of you may wish to investigate.

The sportsmen's magazines reach an enormous field which science educators refuse to recognize largely, I am afraid, because they are not ordinarily trained too well in field natural history. Olaus Murie and his kind are leaders in this field of course, but they have not always reached the audience that most needs their work.

I firmly believe that all nature writers owe it to themselves and to their field to make some contributions to the general educational journals. They need help and generally do not recognize that they do. If nothing else, it would be profitable if the editors of straight educational journals and popular periodicals were attracted to our field. Some of you may very well crash this field and may reap an appropriate reward.

Those of you who have known me through the years know that I get a kick out of writing in protest against things which I think are wrong. I can best sum up an evaluation of that sort of thing by saying that it probably gives the greatest of all self-satisfaction, and when that is said, you should use an extra large period and call it quits until you boil over again.

I started my *Fieldbook of Natural History* as an insurance policy for a boy who was not well. When he died I almost abandoned the project as too expensive in time and money to maintain. One of my artists who demanded more pay told me that she was sure that no book of that type could ever be a financial success—and yet she wanted me to dig in and pay her more. I then after the death of my son set out to write the book without thought of financial reward but to make it useful to science teachers and home folks over a wide geographical area. My publisher protested inclusion of domestic species, and when later I wrote my *Fieldbook of Mammals*, the author of another mammal book wrote and told me that mine was not a mammal book because it included so many domestic and exotic species. I find it hard to understand these objections but easy to accept the returns from the books.

I am sure that nature writing offers a wonderful avenue for people to express themselves in a worthy field. A week ago I talked with an editor in a major publishing field and was told that the conservation field offered no possible rewards. I am tempted to try to make him eat his words just as I made my publisher who objected to the use of domestic species in my books make a retraction. I am sorry to see the old Nature Magazine change but have hopes that it may be entering a more rewarding and influential field. I hope that it makes the most of its opportunities. I am certain of one thing in all of this discussion and that is that careful work in the nature field can supply a sustained royalty in funds, prestige, and

self satisfaction. I am satisfied that writing in this field must have a purpose, possibly stimulated by rebellion against some conditions that exist, and that they may certainly make a retirement a more pleasant experience than it might be did we not have them as a sort of insurance policy to meet a changing future. Robins are going to lay blue eggs in mud-lined nests for a long while, and people are going to be interested in them long after we have gone, providing the chemists do not kill off all our wildlife with their sprays or completely destroy our population with their bombs. Even if they do bring this about we can have a grin on our faces if we end the trip on earth working hard for the kind of things in which we believe.

Book Reviews

ANATOMY OF SEED PLANTS, Katherine Esau, 376 pp., $6.95, John Wiley & Sons, Inc., New York, New York, 1960.

This book is a shorter version of the same subject covered by the author in her comprehensive *Plant Anatomy* of 1953 which was recognized as a most outstanding treatment of the subject and was widely adopted as a text. The new book is an equally fine work, and because of its smaller size and lower price, should prove a more satisfactory text for undergraduate college courses than the earlier volume. The book includes some new material so it is more than a mere condensation of the larger work. For the high school teacher desiring to build up the collection of botanical works in the library, this book is recommended as a worthy addition.

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PERSONAL AND COMMUNITY HEALTH, C. E. Turner, 446 pp., $5.50, The C. V. Mosby Company, St. Louis, Missouri, 1959.

A pioneer health text for college students in its latest revision. The two main sections of the book concern personal and community health. There is an interesting informational appendix on the chief and common diseases. Also there is an interesting list of suffixes and prefixes useful for the understanding of medical and biological terms. There is still a disturbing emphasis on anatomy which leads one to wonder when this aspect of health may be assumed to have been learned. There are references throughout to the professional organizations involved in each subject area to which the student may refer. Safety is a single chapter. There is no concerted treatment of the problems of physical growth. A standard text which might be used as a reference to improve the quality of the usual high school health course. P. K.

FUNCTION OF THE HUMAN BODY, Arthur C. Guyton, 584 pp., W. B. Saunders Company, Philadelphia, Pennsylvania, 1959.

A new textbook of human physiology with the chief emphasis on homeostasis. It is written without elaborate references and in language which the usual student who takes such a service course can well understand. There are excellent diagrams and an easy reading style is apparent throughout. Anatomy is not featured. The chemistry involved is presented in an easy manner which will not require an elaborate chemical background. The book will make a nice high school reference. P. K.

THE BIRTH OF NEW PHYSICS, I. Bernard Cohen, 200 pp., $ .95, Anchor Books, Doubleday & Company, Inc., Garden City, New York, 1960.

Still another of the monographs produced by the Physical Science Study Committee. The distinguished author uses the historical method to introduce the concepts of Newtonian physics by describing the work of Copernicus, Galileo, Kepler, and Aristotle. He describes carefully the evolution of the law of gravitation as a master stroke to explain the strange conclusions Newton's predecessors were forced into in understanding motion, planetary movements, and inertia. P.K.

CRYSTALS AND CRYSTAL GROWING, Alan Holden and Phylis Singer, 320 pp., $1.45, Anchor Books, Doubleday & Company, Inc., 1960.

Another of the Physical Science Study Committee monographs. Although there is not much of direct relevancy to biology, it is an interestingly written and illustrated volume. There are many project suggestions, recipes, bibliographies, and detailed ideas for future student investigations. Although this subject is traditionally in the chemistry curriculum, the fact that this volume and others are produced under PSSC auspices indicates that science is indeed closely interrelated. P. K.

THE PHYSICS OF TELEVISION, Donald G. Fink and David M. Lutyens, 160 pp., $ .95, Anchor Books, Doubleday & Company, Inc., Garden City, New York, 1960.

Another one of the series produced by the Physical Science Study Committee. But don't let the title fool you. This is an excellent introduction to electronics explained in vivid and easily

understandable terms. Biology is also included as it pertains to the communication of an image to the brain. Over half of the book is devoted to elementary electronics with excellent treatments of electrical impulses and transmission. The last part is devoted to an explanation of television receivers, transmitters, and cameras. The pedagogical method is an excellent one as a common phenomenon, television, is used as a common thread to teach electronics. P. K.

Slippery Skins of Germs

The slippery skins of germs—key factors in the body's defense against disease—are beginning to give up their secrets. Chemical studies have established a relationship between the chemical structures of these "skins," known as polysaccharides, and the body's ability to produce germ-fighting antibodies, reported Dr. Paul Rebers, assistant professor of immuno-chemistry at the Rutgers Institute of Microbiology. Of the more than 70 different polysaccharides associated with the pneumonia germ, the chemist has determined the chemical structure of one. The structure of only two others has as yet been determined. The amount of antibodies produced to fight a germ depends on the type of sugar molecules and how they link together in the polysaccharide.

"Certain proteins in the blood stream of disease-immune animals, called antibodies, are able to combine specifically with the disease-causing bacteria, often by means of the surface polysaccharides and sometimes through proteins," the biochemist explained. "This combination is an important step in the body's defense system. The nature of this combination is highly specific.